(54) Title: NEURITE GROWTH REGULATORY FACTORS

(57) Abstract

The present invention relates to the therapeutic and diagnostic use of genes and their encoded proteins (termed herein neurite growth regulatory factors). The proteins of the present invention include metalloproteases associated with glioblastoma cells and other malignant tumors which can metastasize to the brain. The CNS myelin associated proteins inhibit neurite outgrowth in nerve cells and neuroblastoma cells, and can also inhibit fibroblast spreading. Such inhibitory proteins include a 35,000 dalton and a 250,000 dalton molecular weight protein and analogs, derivatives, and fragments thereof. The CNS myelin associated inhibitory proteins may be used in the treatment of malignant tumors. The present invention is also directed to antibodies to the CNS myelin associated proteins; such antibodies can be used in the diagnosis and therapies of nerve damage resulting from trauma, infarction, and degenerative disorders of the central nervous system. In a specific embodiment of the invention, monoclonal antibody IN-1 may be used to promote regeneration of nerve fibers over long distances in spinal cord lesions. The metalloproteases of the invention have value in the treatment of nerve damage and of degenerative disorders of the nervous system. The present invention is also directed to inhibitors of the metalloproteases. Such inhibitors in combination with the CNS myelin associated inhibitory proteins can be used in the treatment of malignant tumours.

NEURITE GROWTH REGULATORY FACTORS

5   1.   INTRODUCTION

The present invention is directed to genes and
their encoded proteins which regulate neurite growth,
antibodies thereto, and the therapeutic and diagnostic uses
of such proteins and antibodies. The proteins of the
10 present invention include central nervous system myelin
associated inhibitory proteins, and metalloproteases
associated with malignant tumors, in particular, primary
brain tumors such as glioblastoma and other tumors capable
of metastasizing to and spreading in the brain. The central
15 nervous system myelin associated inhibitory proteins inhibit
neurite outgrowth and fibroblast spreading and can have
important uses in the treatment of malignant tumors.
Antibodies to such inhibitory proteins can have uses in the
diagnosis of malignant tumors and in the treatment of
20 central nervous system damage and degenerative nerve
diseases. In a specific embodiment of the invention,
antibody to neurite growth inhibitor may be used to promote
the regeneration of neurons over long distances following
spinal cord damage. The metalloproteases of the invention
25 allow invasive growth of glioblastomas and allow neurite
outgrowth in central nervous system tissue. They may have
important uses in the treatment of central nervous system
damage and degenerative nerve diseases. Inhibition of the
metalloprotease can be therapeutically useful in the
30 treatment of malignant tumors.

35

2. BACKGROUND OF THE INVENTION

2.1. FACTORS INFLUENCING NEURITE GROWTH IN THE CENTRAL NERVOUS SYSTEM

Cell attachment, cell spreading, cell motility, and, in particular, neurite outgrowth are strongly dependent on cell-substrate interactions (Sanes, 1983, Ann. Rev. Physiol. 45:581-600; Carbonetto et al., 1987, J. Neurosci. 7:610-620). An increasing number of substrate molecules favoring neuroblast migration or neurite outgrowth have been found in central and peripheral nervous tissue (Cornbrooks et al., 1983, Proc. Natl. Acad. Sci. USA 80:3850-3854; Edelman, 1984, Exp. Cell Res. 161:1-16; Liesi, 1985, EMBO J. 4:1163-1170; Chiu, A.Y. et al., 1986, J. Cell Biol. 103:1383-1398; Fischer et al., 1986, J. Neurosci. 6:605-612; Lindner et al., 1986, Brain Res. 377:298-304; Mirsky et al., 1986, J. Neurocytol. 15:799-815; Stallcup et al., 1986, J. Neurosci. 5:1090-1101; Carbonetto et al., 1987, J. Neurosci. 7:610-620). The appearance of some of these factors can be correlated with specific developmental stages, and, in the peripheral nervous system (PNS), also with denervation (Edelman, 1984, Exp. Cell Res. 161:1-16; Liesi, 1985, EMBO J. 4:1163-1170; Stallcup et al., 1985, J. Neurosci. 5:1090-1101; Daniloff et al., 1986, J. Cell Biol. 103:929-945; Carbonetto et al., 1987, J. Neurosci. 7:610-620). The extracellular matrix protein tenascin has been shown to possess nonpermissive substrate properties (Chiquet-Ehrismann et al., 1986, Cell 47:131-139).

One of the most characterized of the soluble factors favoring neurite outgrowth is nerve growth factor (NGF). NGF promotes nerve fiber outgrowth from embryonic sensory and sympathetic ganglia _in vivo_ and _in vitro_ as well as neurite outgrowth (reviewed in Thoenen et al., 1982, _In:_ Repair and Regeneration of the Nervous System, J.G. Nicholls, ed., Springer-Verlag, NY, pp. 173-185). NGF may also guide the direction of such neurite outgrowth. Three different molecular forms of NGF have been recognized. One

type is a dimer (molecular weight ~26,000) composed of two
noncovalently linked, identical polypeptide chains. The
second form is stable at neutral pH and contains three
different polypeptide chains, α, β and γ (molecular weight
5 ~140,000). The β chain is the biologically active chain and
is identical to the first form of NGF. The third form,
which is isolated primarily from mouse L cells, (see U.S.
Patent No. 4,230,691, by Young, issued October 28, 1980, and
references therein) has a molecular weight of about 160,000
10 but is unstable at neutral pH. NGF has thus far been
isolated from the submandibullar glands of mice, mouse L
cells, and the prostate gland of the guinea pig and bull
(reviewed in Thoenen et al., 1982, supra). No differences
between the biological action of mouse, guinea pig and bull
15 NGF have been detected. In addition, NGF isolated from mice
have been found to bind to the human NGF receptor (Johnson
et al., 1986, Cell 47:545-554).

The differentiated central nervous system (CNS) of
higher vertebrates is capable of only very limited
20 regenerative neurite growth after lesions. Limited
regeneration after lesion has been seen in the retina
(McConnell and Berry, 1982, Brain Res. 241:362-365) and in
aminergic unmyelinated fiber tracts after chemical
(Bjorklund and Stenevi, 1979, Physiol. Rev. 59:62-95) but
25 not mechanical lesions (Bregman, 1987, Dev. Brain Res.
34:265-279). Neurite growth from implanted embryonic CNS
tissues in adult rat CNS has been found in some cases to
reach up to 14 mm within some gray matter areas, but has not
been found to exceed 1 mm within white matter (Nornes et
30 al., 1983, Cell Tissue Res. 230:15-35; Bjorklund and
Stenevi, 1979, Physiol. Rev. 59:62-95; Commission, 1984,
Neuroscience 12:839-853). On the other hand, extensive
regenerative growth has been found in the CNS of lower
vertebrates and in the peripheral nervous system of all
35 vertebrates including man. Results from transplantation
experiments indicate that the lack of regeneration is not an

intrinsic property of CNS neurons, as these readily extend
processes into implanted peripheral nervous tissue (Benfey
and Aguayo, 1982, Nature (London) 296:150-152; Richardson et
al., 1984, J. Neurocytol. 13:165-182 and So and Aguayo,

5   1985, Brain Res. 328:349-354). PNS neurons, however, failed
to extend processes into CNS tissue, thus indicating the
existence of fundamental differences between the two tissues
(Aguayo et al., 1978, Neurosci. Lett. 9:97-104; Weinberg and
Spencer, 1979, Brain Res. 162:273-279).

10   One major difference between PNS and CNS tissue is
the differential distribution of the neurite outgrowth
promoting extracellular matrix component laminin (Liesi,
1985, EMBO J. 4:2505-2511; Carbonetto et al., 1987, J.
Neurosci. 7:610-620). Other factors though may be involved.

15 Drastic differences have been observed in neurite growth
supporting properties of sciatic and of optic nerve explants
in vitro, in spite of the presence of laminin
immunoreactivity in both explants (Schwab and Thoenen, 1985,
J. Neurosci. 5:2415-2423). These experiments were carried

20 out in the presence of optimal amounts of neurotrophic
factors and differences persisted upon freezing of tested
substrates.

            It has been suggested that the differentiated CNS
may lack cellular or substrate constituents that are

25 conducive for neurite growth during development (Liesi,
1985, EMBO J. 4:2505-2511; and Carbonetto et al, 1987, J.
Neurosci. 7:610-620), or it may contain components which are
nonpermissive or inhibitory for nerve fiber regeneration
(Schwab and Thoenen, 1985, J. Neurosci. 5:2415-2423).

30   Recently, a growth (cell proliferation) inhibitory
factor for mouse neuroblastoma cells was partially purified
and characterized from the culture medium of fetal rat
glioblasts as well as from C6 rat glioma cells (Sakazaki et
al., 1983, Brain Res. 262:125-135). The factor was

35 estimated to have a molecular weight of about 75,000 by gel
filtration with BioGel P-20 with an isoelectric point of

5.8. The factor did not appear to alter the growth rate or
morphology of glial cells (C6) or fibroblasts (3T3). In
addition, no significant nerve growth inhibitory factor
activity was detected towards neuroblastoma cells (Neuro La,
NS-20Y and NIE-115) or cloned fibroblasts (3T3).

 Caroni and Schwab (1988, J. Cell Biol. 106:1281-
1288) demonstrated the existence of 35 kD and 250 kD myelin
membrane-bound proteins with potent nonpermissive substrate
properties for neurite growth and fibroblast spreading in
vitro. Caroni and Schwab (March 1988, Neuron 1:85-96)
demonstrated that monoclonal antibodies (termed IN-1 and
IN-2) raised against the inhibitory substrate proteins
neutralized or greatly reduced the nonpermissiveness of both
the 35 kD and 250 kD inhibitors, of isolated myelin membrane
fractions, of cultured highly branched oligodendrocytes, and
of adult rat optic nerve explants.

2.2. PROTEASES AND THEIR INHIBITORS

 Different proteolytic activities have in the past
been shown to be increased in tumorigenic cell lines
(Matrisian et al., 1986, Proc. Natl. Acad. Sci. U.S.A.
83:9413-9417; Mignatti et al., 1986, Cell 47:487-498), in
primary tumor explants (Mullins and Rohrlich, 1983, Biochem.
Biophys. Acta 695:177-214), or in transformed cells
(Quigley, 1976, J. Cell Biol. 71:472-486; Mahdavi and Hynes,
1979, Biochem. Biophys. Acta 583:167-178; Chen et al., 1984,
J. Cell Biol. 98:1546-1555; Wilhelm et al., 1987, Proc.
Natl. Acad. Sci. U.S.A. 84: 6725-6729). One such group of
proteases, metalloproteases has been shown to be involved in
a number of membrane events, including myoblast fusion
(Couch and Stritmatter, 1983, Cell 32:256-265), and
exocytosis in mast cells (Mundy and Stritmatter, 1985, Cell
40:645-656).

 The isolation and characterization of a plasma
membrane-bound metalloprotease (endopeptidase 24.11,
enkephalinase) was reported by Almenoff and Orlowski (1983,

Biochemistry 22:590-599). A metalloprotease expressed by
Rous sarcoma virus transformed chick embryo fibroblasts
which degrades fibronectin and which was localized at
adhesion sites and on "invadopodia" was described by Chen
5 and Chen (1987, Cell 48:193-203).

Studies indicate that proteases and their
inhibitors can influence neurite extension in neuroblastoma
cells (Monard et al., 1983, Prog. Brain Res. 58:359-363) and
in cultured neonatal mouse sensory ganglia (Hawkins and
10 Seeds, 1986, Brain Res. 398:63-70). Cultured glial cells
and gliomas were found to release a 43 kD protein, a glia
derived neurite promoting factor (GdNPF), which induces
neurite outgrowth in neuroblastoma cells but inhibits cell
migration (Monard, et al., 1983, supra). GdNPF was shown to
15 be a very potent inhibitor of cell surface associated serine
protease activity. Neurite outgrowth from normal mouse
sensory ganglia can be enhanced by the addition of serine
protease inhibitors, ovomucoid trypsin inhibitor, leupeptin,
soybean trypsin inhibitor, or thrombin (Hawkins and Seeds,
20 1986, supra). In contrast, proteases were found to inhibit
such neurite outgrowth. Results from preliminary studies
indicate that such proteases possess a thrombin or trypsin
like activity (Hawkins and Seeds, 1986, supra).

Other proteases have also been characterized
25 though their functional role in neurite outgrowth is as yet
unknown. These include a urokinase-like plasminogen
activator and a calcium dependent metalloprotease released
by sympathetic and sensory rat neurons (Pittman, 1985, Dev.
Biol. 110:911-101). The metalloprotease was found to have a
30 molecular weight of 62 kD, to require 1 mM Ca^{2+} for calcium
activity, and to degrade native and denatured collagen more
readily than casein, albumin, or fibronectin. The
plasminogen activator was found to have a molecular weight
of 51 kD, and was precipitated by a rabbit antiserum
35 produced against human urokinase. It may be converted to
its active form of 32 kD.

2.3. NEUROBLASTOMA

Neuroblastoma arises from neuroectoderm and
contains anaplastic sympathetic ganglion cells (reviewed in
Pinkel and Howarth, 1985, In: Medical Oncology, Calabrese,
5 P., Rosenberg, S.A., and Schein, P.S., eds., MacMillan, NY,
pp. 1226-1257). One interesting aspect of neuroblastoma is
that it has one of the highest rates of spontaneous
regression among human tumors (Everson, 1964, Ann. NY Acad.
Sci. 114:721-735) and a correlation exists between such
10 regression and maturation of benign ganglioneuroma (Bolande,
1977, Am. J. Dis. Child. 122:12-14). Neuroblastoma cells
have been found to retain the capacity for morphological
maturation in culture. The tumors may occur anywhere along
the sympathetic chain, with 50% of such tumors originating
15 in the adrenal medulla.

Neuroblastoma affects predominantly preschool aged
children and is the most common extracranial solid tumor in
childhood, constituting 6.5% of pediatric neoplasms. One
half are less than two years of age upon diagnosis.
20 Metastases are evident in 60% of the patients at
presentation usually involving the bones, bone marrow,
liver, or skin. The presenting symptoms may be related to
the primary tumor (spinal coral compression, abdominal
mass), metastatic tumor (bone pain) or metabolic effects of
25 substances such as catecholamines or vasoactive polypeptides
secreted by the tumor (e.g. hypertension, diarrhea).

Experimental evidence indicates that an altered
response to NGF is associated with neuroblastoma (Sonnenfeld
and Ishii, 1982, J. Neurosci. Res. 8:375-391). NGF
30 stimulated neurite outgrowth in one-half of the
neuroblastoma cell lines tested; the other half was
insensitive. However, NGF neither reduced the growth rate
nor enhanced survival in any neuroblastoma cell line.

Present therapies for neuroblastoma involve
35 surgery and/or chemotherapy. Radiation therapy is used for
incomplete tumor responses to chemotherapy. There is a 70-

100% survival rate in individuals with localized tumors, but
only a 20% survival rate in those with metastatic disease
even with multiagent chemotherapy. It appears that patients
less than one year have a better prognosis (70%) than older

5 children.

2.4. GLIOBLASTOMA

Glioblastoma is a highly malignant astrocytic
tumor usually located in the cerebral hemisphere.
10 Astrocytes appear to be a supporting tissue for neurons and
comprise the vast majority of the intraparenchymal cells of
the brain (reviewed in Cutler, 1987, In: Scientific
American Medicine V. 2, Rubenstein and Federman, eds.,
Scientific American, Inc., NY, pp. 1-7). Results from a
15 survey conducted by the National Institute of Neurological
and Communicative Disorders and Stroke indicated that the
incidence of primary brain tumors in the United States is
approximately eight per 100,000, in which 20% of those
tumors are glioblastomas. These tumors are generally found
20 in individuals between 45 and 55 years of age. The tumors
may also involve multiple lobes and may rupture into the
ventricular system or extend across the corpus collosum to
the opposite hemisphere. Due to the resulting increase in
intracranial pressure, symptoms of tumor growth include
25 headache, nausea and vomiting, mental status changes, and
disturbances of consciousness. Due to their highly invasive
properties, glioblastomas are associated with a poor
prognosis. Chemotherapeutic agents or radiotherapies may be
used. However, patients generally do not survive longer
30 than two years even with these therapies.

3. SUMMARY OF THE INVENTION

The present invention relates to genes and their
encoded proteins which regulate neurite growth and the
35 diagnostic and therapeutic uses of such proteins. Such
proteins are termed herein neurite growth regulatory

factors. The neurite growth regulatory factors of the
present invention include, in one embodiment, central
nervous system myelin associated proteins which inhibit
neurite outgrowth, and are termed herein neurite growth
5   inhibitory factors. Another embodiment of the invention is
directed to neurite growth regulatory factors which are
metalloproteases associated with malignant tumors, in
particular, those tumors metastatic to the brain. Such
metalloproteases enable the malignant cells to overcome the
10 inhibitory CNS environment and invade large areas of brain
and spinal cord.

The CNS myelin associated proteins inhibit neurite
outgrowth in nerve cells and neuroblastoma cells and also
inhibit the spreading of fibroblasts and melanoma cells.
15 Such inhibitory proteins include but are not limited to
35,000 dalton and a 250,000 dalton molecular weight proteins
and analogs, derivatives, and fragments thereof. The CNS
myelin associated inhibitory proteins may be used in the
treatment of patients with malignant tumors which include
20 but are not limited to melanoma and nerve tissue tumors
(e.g., neuroblastoma). The absence of the myelin associated
inhibitory proteins can be diagnostic for the presence of a
malignant tumor such as those metastatic to the brain (e.g.,
glioblastoma). The present invention also relates to
25 antagonists of the CNS myelin associated inhibitory
proteins, including, but not limited to, antibodies, i.e.
antibodies IN-1 or IN-2. Such antibodies can be used to
neutralize the neurite growth inhibitory factors for
regenerative repair after trauma, degeneration, or
30 inflammation. In a further specific embodiment, monoclonal
antibody IN-1 may be used to promote regeneration of nerve
fibers over long distances following spinal cord damage.

The present invention further relates to neurite
growth regulatory factor receptors and fragments thereof as
35 well as the nucleic acid sequences coding for such neurite
growth regulatory factor receptors and fragments, and their

therapeutic and diagnostic uses. Substances which function
as either agonists or antagonists to neurite growth
regulatory factor receptors are also envisioned and within
the scope of the present invention.

5   The metalloproteases of the present invention can
be found associated with malignant tumors, in particular,
those capable of metastasizing to the brain. In a specific
embodiment, the metalloprotease is associated with membranes
of glioblastoma cells. The metalloproteases, and analogs,

10 derivatives, and fragments thereof can have value in the
treatment of nerve damage resulting from trauma, stroke,
degenerative disorders of the central nervous system, etc.
In another embodiment of the invention, the metalloprotease
may be used in combination with antibodies to the neurite

15 growth inhibitory factors to treat nerve damage.
           The present invention is also directed to
inhibitors of and/or antibodies to the metalloproteases of
the invention. Such inhibitors and/or antibodies can be
used in the diagnosis and/or treatment of malignant tumors

20 such as those which can metastasize to the brain, including
but not limited to glioblastomas. Alternatively, the
metalloprotease inhibitors, in combination with CNS myelin
associated inhibitory protein or analogs, derivatives, or
fragments thereof, may be used in the treatment and/or

25 diagnosis of malignant tumors including but not limited to
glioblastoma, neuroblastoma, and melanoma.

3.1. DEFINITIONS
           As used herein, the following terms shall have the
30 meanings indicated:

BSA: bovine serum albumin

cbz-tyr-tyr: carbobenzoxy-tryosine-tyrosine

cbz-gly-phe-NH$_2$:   carbobenzoxy-glycine-phenylalanine-
35   amide

cbz-ala-phe-NH$_2$:	carbobenzoxy-alanine-phenylalanine-amide
cbz-phe-phe-NH$_2$:	carbobenzoxy-phenylalanine-phenylalanine-amide
5 cbz-gly-phe-phe-NH$_2$:	carbobenzoxy-glycine-phenylalanine-phenylalanine-amide
CNS:	central nervous system
CST:	Corticospinal tract
10 DMEM:	Dulbecco's Modified Minimal Essential Media
EDTA:	ethylenediamine tetracetate
EGTA:	ethylene glycol-bis-(β-aminoethyl ether) – N,N,N'-N'-tetracetate
15 FCS:	fetal calf serum
FITC:	fluorescein isothiocyanate
GdNPF:	glial-derived neurite promoting factor
GFAP:	glial fibrillary acid protein
20 HBO:	highly branched oligodendrocyte
Hepes:	N-2-hydroxyethylpiperazine-N'-2-ethanesulfonic acid
IN-1:	a monoclonal antibody against gel-purified 250 kD CNS myelin associated inhibitory protein
25	
IN-2:	a monclonal antibody against gel-purified 35 kD CNS myelin associated inhibitory protein
30 J1:	a cell adhesion molecule of molecular weight 160-180 kD
kD:	kilodalton
Mab:	monoclonal antibody
35 MW:	molecular weight
N-CAM:	neural cell adhesion molecule

NGF:	nerve growth factor
neurite growth	
regulatory factors:	CNS myelin associated 35 kD and 250 kD inhibitory proteins, and a glioblastoma cell membrane associated metalloprotease
PBS:	phosphate buffered saline
PLYS:	poly-D-lysine
PNS:	peripheral nervous system
PORN:	polyornithine
SCG:	superior cervical ganglion
SDS-PAGE:	sodium dodecyl sulfate-polyacrylamide gel electrophoresis
Tris:	Tris (hydroxymethyl) aminomethane

4. DESCRIPTION OF THE FIGURES

Figure 1. Sympathetic (a-d) or retinal (e) neurons plated into cultures of optic nerve glial cells show nonpermissive substrate effect of highly branched oligodendrocytes and the absence of such effect in immature oligodendrocytes. Figures 1a, c, e, g show phase contrast pictures. Figures 1b, d, f show immunofluorescence with antibody O_4. Figure 1h shows immunofluorescence with antibody O_1.

Figures 1a and 1b show "windows" (areas free of neurites) formed by highly branched oligodendrocytes (10-day-old optic nerves, 18 days in vitro) in the neurite plexus of sympathetic neurons (a: 8 days in vitro; b: 4 days in vitro). Magnification: x120. In Figure 1b, a neurite changing its direction is seen (arrow-head). Schwann cells also avoid the oligodendrocyte.

Figures 1c and 1d show antibody O_4-positive oligodendrocytes (from 10-day-old optic nerves, 7 days in vitro) surrounded by plexus of sympathetic neurites (5 days in vitro). Magnification: x220. Neurites

characteristically "loop around" the oligodendrocytes. The
occasional spanning of neurite bundles over nonpermissive
oligodendrocytes occurs as a secondary event.

Figures 1e and 1f show that antibody O_4-positive
5 cells with the typical morphology of immature
oligodendrocytes are permissive for sympathetic neurites
(arrow-heads) (5 days in vitro). Magnification: x380.

Figures 1g and 1h show that E 20 rat retinal cells
(2 days in vitro) do not adhere or grow neurites onto highly
10 branched, antibody O_1-positive oligodendrocytes.
Magnification:x 200.

Figure 2. A, B: Histograms showing the frequency
of interactions/overlap of sympathetic neurites and Schwann
cells with highly branched (A) or immature (B)
15 oligodendrocytes. Glial cells from 8 to 10-day optic nerves
(2 days in vitro) were co-cultured for an additional 2 days
with dissociated neurons from superior cervical ganglia and
then stained with antibody O_4. Oligodendrocytes were
classified by morphology on coded fluorescence pictures. On
20 phase contrast pictures, the fractional area of contact with
neurites and Schwann cells was determined and classified
into 3 categories: < 20 %, 20 to 80 %, or > 80 % of
oligodendrocyte territory covered by neurites or Schwann
cells. Values represent mean frequencies of cells in 3
25 categories ± SEM (standard error of the mean) (4 cultures;
70 to 130 systematically sampled cells per culture).

C, D: Histograms showing the interaction of
retinal cells with highly branched (C) or immature (D)
oligodendrocytes. Glial cultures from adult rat optic
30 nerves (6 - 11 days in vitro) were co-cultured for 1 - 5
days with embryonic rat retinal cells. Antibody O_4 stained
oligodendrocytes were classified morphologically, and the
total area occupied by each oligodendrocyte as well as the
fraction occupied by retinal cells was determined by
35 measuring with a graphic tablet. n = 109.

Figure 3. Astrocytes represent an adhesive substrate for neurons and neurites.

Figures 3a and 3b show sympathetic neurites (13 days in vitro) growing on reactive protoplasmic astrocyte

5 (arrow in a); GFAP-positive (b): from 10-day-old rat optic nerve, 23 days in vitro. Magnification: x220.

Figures 3c and d show retinal cells (from E17 retina, 2 days in vitro) adhering to astrocytes (GFAP-positive, Figure 3d); from 10-day-old optic nerve, 9 days in

10 vitro) with long and with short (arrow) processes. Magnification: x400.

Figure 4. a, b: Highly branched oligodendrocytes (O_4-positive) are non-permissive for attachment and fiber outgrowth of NB-2A neuroblastoma cells. NB-2A cells were

15 cultured for 24 hours on optic nerve glial cells (6-day old rat optic nerves, 3 days in culture) and stimulated for neurite outgrowth by GdNPF (Guenther et al., 1985, EMBO J. 4:1963-1966). NB-2A cells adjacent to oligodendrocytes (short arrows) show assymetric ougrowth; distant cells

20 (long arrows) show random orientation of outgrowth. Magnification: x260. c - f: 3T3 fibroblasts plated at high cell densities into optic nerve glial cultures show nonpermissive substrate effect of highly branched oligodendrocytes (c, e). The oligodendrocyte in c/d has

25 large membrane areas connecting its process network. An immature oligodendrocyte (e, f: arrow; O_4-positive, irregular morphology) is overgrown by spreading fibroblasts. 10- (c, d) and 12-(e, f) day old optic nerves, 2 days in vitro; 3T3 added for 3 hours. d, f: O_4-staining. c, d:

30 magnification is x300; e, f: magnification is x250.

Figure 5. Orientation of neuroblastoma process outgrowth in relation to highly branched oligodendrocytes. Optic nerve glial cells (2 or 6 days in vitro) were co-cultured with NB-2A cells for 24 hours in presence of GdNPF

35 or dibutyryl cAMP. Antibody O_4-positive highly branched oligodendrocytes were systematically sampled and

neighbouring neuroblastoma cells were classified as <u>adjacent</u>
when the distance between the edge of oligodendrocyte
process network and neuroblastoma cell body was less than 2
cell body diameters. Neuroblastoma cells at greater
5 distances were classified as <u>distant</u>. Neuroblastoma
processes were assigned to four sectors (1 - 4) according to
their direction with regard to the closest oligodendrocyte
as illustrated. Values, shown in Table IA (Section
6.2.3.3., <u>infra</u>) represent means ± SEM of 3 experiments (60
10 -100 neurites from 3 cultures per experiment). * p < 0.05;
*** p < 0.001.

Figure 6. Histograms showing the overlap of 3T3
cells with highly branched (A) or immature (B)
oligodendrocytes. 3T3 cells were co-cultured for 3 - 4
15 hours on optic nerve glial cells at high cell density, and
cultures fixed and stained with antibody O_4.
Oligodendrocytes were sampled systematically, classified as
highly branched or immature oligodendrocytes, and their
overlap with 3T3 cells was determined in the 3 categories
20 indicated. Values represent means ± SEM (standard error
measurement) of four experiments (70 - 170 cells).

Figure 7. Inhibition of neurite outgrowth by use
of CNS myelin as a substrate. Sympathetic neurons (from 1-
day-old rat superior cervical ganglia) cultured in the
25 presence of 100 ng/ml NGF for 26 hours on poly-D-lysine
(PLYS)-coated culture dish containing focal spots of CNS or
PNS myelin. CNS myelin (a, c) strongly inhibits neurite
outgrowth; PNS myelin (b, d) is a permissive substrate. In
c and d, the border of a myelin islet on the PLYS is shown.
30 Magnification: x75.

Figure 8. Nonpermissive substrate effects of CNS
myelin but <u>not</u> PNS myelin for neurite outgrowth from
neuroblastoma cells (A) and for 3T3 cell spreading (B).

Figure 8A shows neuroblastoma cells cultured for 5
35 hours in the presence of 2 mM dibutyrylcyclic AMP on PLYS
(solid bars), CNS myelin coated PLYS (hatched bars), or PNS

myelin-coated PLYS (open bars). Cells were classified as round cells, filopodia or short process carrying cells, or cells with processes longer than 1 cell diameter. Values represent means ± SEM of 3 cultures (250 - 450 cells per culture).

Figure 8B shows 3T3 cells cultured for 1 hour on PLYS, CNS myelin-coated PLYS, or PNS myelin-coated PLYS. Cells were classified as round cells, cells with filopodia or short processes, or large flat cells. Values represent means ± SEM of 3 cultures (300 - 400 cells per culture).

Figure 9. C6, but not 3T3 cells, infiltrate optic nerve explants. Phase-contrast microphotographs of 10 μm frozen sections of rat optic (a,b) or sciatic (c,d) nerve explants, after 2 weeks incubation with C6 (a,c) or 3T3 (b,d) cells. Cells were added to one tip of the explants. Infiltrated cells can be seen after cresyl violet staining in both sciatic nerves (c,d) but only for C6 cells in the optic nerve (a). Arrows in (b) point to few 3T3 cells adjacent to blood vessels. Bar, 0.2 mm.

Figure 10. C6, but not 3T3 or B16 cells attach and spread on CNS white matter of rat cerebellar frozen sections. Phase contrast micrographs of rat cerebellar frozen sections (25 μm) on which C6 (a,b), 3T3 (c,d) or B16 (e) cells were cultured for 2 days. A clear difference on white matter (wm) emerges for 3T3 and B16 cells compared to C6 cells. gl: granular layer, ml: molecular layer. Gray matter is composed of granular and molecular layer. Bar, 0.3 mm.

Figure 11. C6 cells overcome the inhibitory substrate property of CNS myelin. Spreading of C6 (a), 3T3 (b) and B16 (c) cells on PLYS or CNS myelin. Spreading is calculated as described in Section 9.1.3., infra using electron micrographs. 0% spreading: round cells; 100% spreading was taken as the average value at 300 minutes.

Figure 12. 1,10-phenanthroline inhibits C6
spreading specifically on CNS myelin. C6 cells were
cultured for 3 hours on the indicated substrates in the
presence of increasing doses of 1,10-phenanthroline.
5 Spreading was inhibited by low doses exclusively on CNS
myelin. 1,10-phenanthroline concentrations above 0.5 mM
exert a general toxic effect on all substrates. Spreading
was quantified as indicated in Figure 11.

Figure 13. Degradation of CNS inhibitory
10 substrate by C6 plasma membranes is 1,10-phenanthroline
sensitive. Spreading of 3T3 cells on CNS myelin was induced
by pretreatment of myelin with C6 plasma membranes. 1,10-
phenanthroline abolished this effect. Shown are phase
contrast micrographs of 3T3 cells on polylysine (PLYS) (a),
15 on CNS myelin (b), on CNS myelin pretreated with C6 plasma
membranes, and on CNS myelin pretreated with C6 plasma
membranes (C6-PM) in the presence of 1,10-phenanthroline.

Figure 14. C6 cell attachment and spreading on
CNS white matter of rat cerebellar frozen section is
20 impaired by metalloprotease blockers. Phase contrast
micrographs of C6 cells on rat cerebellar frozen sections
cultivated in the presence of either 0.1 mM cbz-ala-phe (a)
or 0.1 mM cbz-tyr-tyr (b). Inhibition of attachment and
spreading is particularly evident in the center of the white
25 matter (asterisks), but is also visible in the main white
matter branches (arrows).

Figure 15. C6 cell infiltration into CNS explants
is impaired by cbz-tyr-tyr. Cells were added to one tip of
optic nerve explants (chamber cultures) in the presence of
30 the metalloprotease inhibitor cbz-tyr-tyr, or of the control
peptide cbz-ala-phe 14 day old cultures were quantified.
Infiltrated cells were counted in the first 1.3 mm of the
explants. Each column represents the number of infiltrated
cells per 0.1 mm. Only the most central part of the
35 explants was considered (0.25 mm). Values represent means $\pm$
SEM of two sets of experiments for a total of 8 explants.

Figure 16. Tumor of antibody-secreting mouse IN-1 hybridoma cells in the cortex of an 8 day old rat. 1 mio. cells (in 2 µl) were injected at P2; (a) Cresyl violet stained frozen section (15 µl) shows well circumscribed,

5 compact tumor (arrow); (b) Antibody production demonstrated by immunofluorescence with anti-mouse-Ig-FITC. Tumor and surrounding tissue up to the lateral ventricle (small arrow) are strongly stained (adjacent section to a). Rat was fixed by perfusion with 4% formaldehyde in phosphate buffer.

10 Magnification: 6.4 x

Figure 17. Labelled corticospinal tract fibers are present far distal to spinal cord lesions in 4 IN-1 treated rats (top), but not in 4 control anti-HRP treated animals (bottom). Camera lucida drawings of longitudinal

15 sections of spinal cords (75 µ total thickness, 3 superimposed 25 µ sections) showing labelling pattern of CST fibers labelled by anterograde transport of WGA-HRP. Long-distance elongation of regeneration CST fibers is present in the IN-1 treated rats. Arrow points to lesion sites, which

20 sometimes contain small caverns communicating with the central canal.--r: rostral; c: caudal.

Figure 18. Dark-field micrographs of spinal cord longitudinal sections of an IN-treated rat (a-d) and an anti-HRP-treated rat (e-g). high magnification micrographs

25 show the densely labelled CST with a broad sprouting zone rostral to the lesion (b and f). Fine grain specific label (arrows) is seen immediately caudal to the lesion in both animals (b, f). Label is also present far distal (about 7 mm) in the IN-treated spinal cord (c,d). In contrast, no

30 such label was detectable in the anti-HRP-treated rat (g). Large white dots (crystals) in all sections represent reaction product in blood vessels, always prominant in material reated with this highly sensitive procedure. c=caudal; L=lesion; r=rostral.

35   Magnification: a,e: 14 x; b,f,g: 70 x; c,d: 140 x.

5. DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to genes and their encoded proteins which regulate neurite growth and the diagnostic and therapeutic uses of such proteins. The
5   proteins of the present invention (termed herein neurite growth regulatory factors) include proteins associated with central nervous system myelin with highly nonpermissive substrate properties, termed herein neurite growth inhibitory factors. The neurite growth regulatory factors
10   also include metalloproteases which can be found associated with malignant tumors, in particular, those tumors metastatic to the brain.

The CNS myelin associated proteins of the invention inhibit neurite outgrowth in nerve cells or
15   neuroblastoma cells. The protein can also inhibit fibroblast spreading and migration. These inhibitory proteins are active cross-species and may be used in the treatment of patients with malignant tumors including but not limited to melanoma and tumors of nerve tissue (e.g.
20   neuroblastoma). In a specific example of the present invention, a 35 kilodalton and a 250 kilodalton CNS myelin associated protein are described.

The present invention is also directed to antibodies to the CNS myelin associated proteins and their
25   therapeutic and diagnostic uses. These antibodies can be used in the treatment of nerve damage resulting from, e.g., trauma (e.g., spinal cord injuries), stroke, degenerative disorders of the central nervous system, etc. In particular, antibodies to CNS myelin associated proteins may
30   be used to promote regeneration of nerve fibers. In a specific embodiment of the invention, monoclonal antibody IN-1 may be used to promote the regeneration of nerve fibers over long distances following spinal cord damage.

The present invention further relates to neurite
35   growth regulatory factor receptors and peptide fragments thereof as well as the nucleic acid sequences coding for

neurite growth regulatory factor receptors and fragments, and their therapeutic and diagnostic uses. Antibodies to neurite growth regulatory factor receptors are also envisioned and within the scope of the present invention.

5   The present invention is also directed to metalloproteases associated with malignant tumors, in particular, those metastatic to the brain. In a specific embodiment, the metalloprotease is associated with glioblastoma cells. The metalloproteases of the invention

10   are associated with the CNS infiltration activity of malignant cells, and can neutralize the inhibitory substrate properties of the CNS myelin-associated proteins. The metalloproteases can have therapeutic value in the treatment of nerve damage such as that resulting from traumatic injury

15   (e.g. spinal cord injuries), stroke, degenerative disorders of the central nervous system, etc. Alternatively, the metalloprotease may be used in combination with antibodies directed against myelin associated inhibitory proteins to treat nerve damage.

20   The present invention is also directed to inhibitors of the metalloproteases. Such inhibitors can impair malignant cell spreading and infiltration, and can be used in the treatment of malignant tumors (e.g. glioblastoma). In a specific embodiment, the

25   metalloprotease inhibitors in combination with CNS myelin associated inhibitory proteins such as the 35,000 dalton and/or the 250,000 dalton molecular weight proteins or human functional equivalents thereof, may be used in the diagnosis and/or treatment of malignant tumors which include but are

30   not limited to glioblastomas, neuroblastomas, and melanomas.
The method of the invention can be divided into the following stages, solely for the purpose of description: (1) isolation and purification of neurite growth regulatory factors; (2) characterization of neurite growth regulatory

35   factors; (3) molecular cloning of genes or gene fragment encoding neurite growth regulatory factors; (4) production

of antibodies against neurite growth regulatory factors; and
(5) generation of neurite growth regulatory factor related
derivatives, analogs, and peptides. The method further
encompasses the diagnostic and therapeutic uses of neurite
5 growth regulatory factors and their antibodies.

5.1. ISOLATION AND PURIFICATION OF NEURITE GROWTH REGULATORY FACTORS

The present invention relates to CNS myelin
associated inhibitory proteins of neurite growth, receptors
10 of CNS myelin associated inhibitory proteins of neurite
growth, and to metalloproteases such as that associated with
membranes of glioblastoma cells. The CNS myelin associated
inhibitory proteins of the invention may be isolated by
first isolating myelin and subsequent purification
15 therefrom. Similarly, the metalloprotease may be obtained
by isolation from mammalian glioblastoma cells. Isolation
procedures which may be employed are described more fully in
the sections which follow. Alternatively, the CNS myelin
associated inhibitory proteins or the metalloprotease may be
20 obtained from a recombinant expression system (see Section
5.3., infra). Procedures for the isolation and purification
of receptors for the CNS myelin associated inhibitory
proteins are described in Section 5.1.2., infra.

25
5.1.1. ISOLATION AND PURIFICATION OF CNS MYELIN ASSOCIATED INHIBITORY PROTEINS

CNS myelin associated inhibitory proteins can be
isolated from the CNS myelin of higher vertebrates
including, but not limited to, birds or mammals. Myelin can
30 be obtained from the optic nerve or from central nervous
system tissue that includes but is not limited to spinal
cords or brain stems. The tissue may be homogenized using
procedures described in the art (Colman et al., 1982, J.
Cell Biol. 95:598-608). The myelin fraction can be isolated
35 subsequently also using procedures described (Colman et al.,
1982, supra).

In one embodiment of the invention, the CNS myelin associated inhibitory proteins can be solubilized in detergent (e.g., Nonidet P-40™, sodium deoxycholate). The solubilized proteins can subsequently be purified by various
5 procedures known in the art, including but not limited to chromatography (e.g., ion exchange, affinity, and sizing chromatography), centrifugation, electrophoretic procedures, differential solubility, or by any other standard technique for the purification of proteins (see, e.g., Caroni and
10 Schwab, 1988, J. Cell Biol. 106:1281).

Alternatively, the CNS myelin associated inhibitory proteins may be isolated and purified using immunological procedures. For example, in one embodiment of the invention, the proteins can first be solubilized using
15 detergent (e.g., Nonidet P-40™, sodium deoxycholate). The proteins may then be isolated by immunoprecipitation with antibodies to the 35 kilodalton and/or the 250 kilodalton proteins. Alternatively, the CNS myelin associated inhibitory proteins may be isolated using immunoaffinity
20 chromatography in which the proteins are applied to an antibody column in solubilized form.

5.1.2. ISOLATION AND PURIFICATION OF RECEPTORS FOR THE CNS MYELIN ASSOCIATED INHIBITORY PROTEINS

25   Receptors for the CNS myelin associated inhibitory proteins can be isolated from cells whose attachment, spreading, growth and/or motility is inhibited by the CNS myelin associated inhibitory proteins. Such cells include but are not limited to fibroblasts and neurons. In a
30 preferred embodiment, fibroblasts are used as the source for isolation and purification of the receptors.

     In one embodiment, receptors to CNS myelin associated inhibitory proteins may be isolated by affinity chromatography of fibroblast cell extracts, in which a
35 myelin associated inhibitory protein or peptide fragment thereof is immobilized to a solid support.

5.1.3. ISOLATION AND PURIFICATION OF METALLOPROTEASES ASSOCIATED WITH MALIGNANT TUMORS

The metalloproteases of the present invention may be isolated from cells of malignant tumors, in particular, those tumors which can metastasize to the brain. In a preferred embodiment, a metalloprotease can be isolated from mammalian glioblastoma cells. In a preferred method, the metalloprotease is isolated from the plasma membrane fraction of such cells. The cells may be obtained by dissociating and homogenizing tumors using procedures known in the art or from tumor cell lines. Plasma membrane fractions may be obtained using procedures known in the art, e.g., gradient centrifugation (Quigley, 1976, J. Cell Biol. 71:472-486). The metalloprotease may be isolated from the membranes by solubilization with mild ionic or nonionic detergent (e.g., deoxycholate, Nonidet P-40™, Triton™, Brij™) using procedures described in the art (reviewed in Cooper, 1977, In Tools of Biochemistry, John Wiley & Sons, NY, pp. 355-406).

Purification of the metalloprotease can be carried out by known procedures, including but not limited to chromatography (e.g., ion exchange, affinity, and sizing column chromatography), centrifugation, electrophoretic procedures, differential solubility, or by any other standard technique for the purification of proteins.

5.2. PROTEIN CHARACTERIZATION

The neurite growth regulatory factors of the present invention can be analyzed by assays based on their physical, immunological, or functional properties. The half life of the neurite growth regulatory factors in cultured cells can be studied, for example, by use of cycloheximide, an inhibitor of protein synthesis (Vasquez, 1974, FEBS Lett. 40:563-584). In other experiments, a physiological receptor for a neurite growth regulatory factor could be identified by assays which detect complex formation with a neurite growth regulatory factor, e.g., by use of affinity

chromatography with immobilized neurite growth regulatory factor, binding to a labeled neurite growth regulatory factor followed by cross-linking and immunoprecipitation, etc.

5   Electrophoretic techniques such as SDS-polyacrylamide gel electrophoresis and two-dimensional electrophoresis can be used to study protein structure. Other techniques which can be used include but are not limited to peptide mapping, isoelectric focusing, and
10 chromatographic techniques.

The amino acid sequences of primary myelin associated inhibitors or of the metalloprotease can be derived by deduction from the DNA sequence if such is available, or alternatively, by direct sequencing of the protein, e.g., with
15 an automated amino acid sequencer. The protein sequences can be further characterized by a hydrophilicity analysis (Hopp and Woods, 1981, Proc. Natl. Acad. Sci. U.S.A. 78:3824-3828). A hydrophilicity profile can be used to identify the hydrophobic and hydrophilic regions of the protein (and the
20 corresponding regions of the gene sequence, if available, which encode such regions).

Secondary structural analysis (Chou and Fasman, 1974, Biochemistry 13:222) can also be done, to identify regions of the CNS myelin associated inhibitor or gliobastoma
25 metalloprotease sequence that assume specific secondary structures. Other methods of structural analysis can also be employed. These include but are not limited to X-ray crystallography (Engstom, 1974, Biochem. Exp. Biol. 11:7-13) and computer modeling (Fletterick, R. and Zoller, M. (eds.),
30 1986, Computer Graphics and Molecular Modeling, in Current Communications in Molecular Biology, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York).

35

5.3. MOLECULAR CLONING OF GENES OR GENE FRAGMENTS ENCODING NEURITE GROWTH REGULATORY FACTORS

5.3.1. ISOLATION AND CLONING OF THE NEURITE GROWTH REGULATORY FACTOR GENES

Any mammalian cell can potentially serve as the nucleic acid source for the molecular cloning of the genes encoding the CNS myelin associated inhibitory proteins, including but not limited to the 35 kD and/or 250 kD myelin associated proteins described in Caroni and Schwab (1988, Neuron 1:85-96), or the glioblastoma associated metalloprotease, hereinafter referred to as neurite growth regulatory factor genes.

The DNA may be obtained by standard procedures known in the art from cloned DNA (e.g., a DNA "library"), by chemical synthesis, by cDNA cloning, or by the cloning of genomic DNA, or fragments thereof, purified from the desired mammalian cell. (See, for example, Maniatis et al., 1982, Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York; Glover, D.M. (ed.), 1985, DNA Cloning: A Practical Approach, MRL Press, Ltd., Oxford, U.K., Vol. I, II.) Clones derived from genomic DNA may contain regulatory and intron DNA regions, in addition to coding regions; clones derived from cDNA will contain only exon sequences. Whatever the source, a given neurite growth regulatory factor gene should be molecularly cloned into a suitable vector for propagation of the gene.

In the molecular cloning of a neurite growth regulatory factor gene from genomic DNA, DNA fragments are generated, some of which will encode the desired neurite growth regulatory factor gene. The DNA may be cleaved at specific sites using various restriction enzymes. Alternatively, one may use DNAse in the presence of manganese to fragment the DNA, or the DNA can be physically sheared, as for example, by sonication. The linear DNA fragments can then

be separated according to size by standard techniques, including but not limited to, agarose and polyacrylamide gel electrophoresis and column chromatography.

Once the DNA fragments are generated,
5 identification of the specific DNA fragment containing a neurite growth regulatory factor gene may be accomplished in a number of ways. For example, if an amount of a neurite growth regulatory factor gene or its specific RNA, or a fragment thereof, is available and can be purified and labeled, the
10 generated DNA fragments may be screened by nucleic acid hybridization to the labeled probe (Benton and Davis, 1977, Science 196:180; Grunstein and Hogness, 1975, Proc. Natl. Acad. Sci. U.S.A. 72:3961-3965). For example, in a preferred embodiment, a portion of a neurite growth regulatory factor
15 amino acid sequence can be used to deduce the DNA sequence, which DNA sequence can then be synthesized as an oligonucleotide for use as a hybridization probe. Alternatively, if a purified neurite growth regulatory factor probe is unavailable, nucleic acid fractions enriched in
20 neurite growth regulatory factor may be used as a probe, as an initial selection procedure.

It is also possible to identify an appropriate neurite growth regulatory factor-encoding fragment by restriction enzyme digestion(s) and comparison of fragment
25 sizes with those expected according to a known restriction map if such is available. Further selection on the basis of the properties of the gene, or the physical, chemical, or immunological properties of its expressed product, as described supra, can be employed after the initial selection.
30 A neurite growth regulatory factor gene can also be identified by mRNA selection using nucleic acid hybridization followed by in vitro translation or translation in Xenopus oocytes. In an example of the latter procedure, oocytes are injected with total or size fractionated CNS mRNA populations,
35 and the membrane-associated translation products are screened in a functional assay (3T3 cell spreading). Preadsorption of

the RNA with complementary DNA (cDNA) pools leading to the
absence of expressed inhibitory factors indicates the presence
of the desired cDNA.   Reduction of pool size will finally lead
to isolation of a single cDNA clone.   In an alternative
5 procedure, DNA fragments can be used to isolate complementary
mRNAs by hybridization.   Such DNA fragments may represent
available, purified neurite growth regulatory factor DNA, or
DNA that has been enriched for neurite growth regulatory
factor sequences. .Immunoprecipitation analysis or functional
10 assays of the _in_ _vitro_ translation products of the isolated
mRNAs identifies the mRNA and, therefore, the cDNA fragments
that contain neurite growth regulatory factor sequences.   An
example of such a functional assay involves an assay for
nonpermissiveness in which the effect of the various
15 translation products on the spreading of 3T3 cells on a
polylysine coated tissue culture dish is observed (see Caroni
and Schwab, 1988 J. Cell Biol. 106:1281).   In addition,
specific mRNAs may be selected by adsorption of polysomes
isolated from cells to immobilized antibodies specifically
20 directed against a neurite growth regulatory factor protein.
A radiolabeled neurite growth regulatory factor cDNA can be
synthesized using the selected mRNA (from the adsorbed
polysomes) as a template.   The radiolabeled mRNA or cDNA may
then be used as a probe to identify the neurite growth
25 regulatory factor DNA fragments from among other genomic DNA
fragments.

        Alternatives to isolating the neurite growth
regulatory factor genomic DNA include, but are not limited to,
chemically synthesizing the gene sequence itself from a known
30 sequence or making cDNA to the mRNA which encodes the neurite
growth regulatory factor gene.   Other methods are possible and
within the scope of the invention.

        The identified and isolated gene or cDNA can then
be inserted into an appropriate cloning vector.   A large
35 number of vector-host systems known in the art may be used.
Possible vectors include, but are not limited to, cosmids,

plasmids or modified viruses, but the vector system must be compatible with the host cell used. Such vectors include, but are not limited to, bacteriophages such as lambda derivatives, or plasmids such as pBR322 or pUC plasmid derivatives.

5   Recombinant molecules can be introduced into host cells via transformation, transfection, infection, electroporation, etc.

In an alternative embodiment, the neurite growth regulatory factor gene may be identified and isolated after insertion into a suitable cloning vector, in a "shot gun"

10 approach. Enrichment for a given neurite growth regulatory factor gene, for example, by size fractionation or subtraction of cDNA specific to low neurite growth regulatory factor producers, can be done before insertion into the cloning vector. In another embodiment, DNA may be inserted into an

15 expression vector system, and the recombinant expression vector containing a neurite growth regulatory factor gene may then be detected by functional assays for the neurite growth regulatory factor protein.

The neurite growth regulatory factor gene is

20 inserted into a cloning vector which can be used to transform, transfect, or infect appropriate host cells so that many copies of the gene sequences are generated. This can be accomplished by ligating the DNA fragment into a cloning vector which has complementary cohesive termini. However, if

25 the complementary restriction sites used to fragment the DNA are not present in the cloning vector, the ends of the DNA molecules may be enzymatically modified. Alternatively, any site desired may be produced by ligating nucleotide sequences (linkers) onto the DNA termini; these ligated linkers may

30 comprise specific chemically synthesized oligonucleotides encoding restriction endonuclease recognition sequences. In an alternative method, the cleaved vector and neurite growth regulatory factor gene may be modified by homopolymeric tailing.

35

Identification of the cloned neurite growth
regulatory factor gene can be accomplished in a number of ways
based on the properties of the DNA itself, or alternatively,
on the physical, immunological, or functional properties of
5 its encoded protein. For example, the DNA itself may be
detected by plaque or colony nucleic acid hybridization to
labeled probes (Benton, W. and Davis, R., 1977, Science
196:180; Grunstein, M. and Hogness, D., 1975, Proc. Natl.
·Acad. Sci. U.S.A. 72:3961). Alternatively, the presence of a
10 neurite growth regulatory factor gene may be detected by
assays based on properties of its expressed product. For
example, cDNA clones, or DNA clones which hybrid-select the
proper mRNAs, can be selected which produce a protein that
.inhibits _in vitro_ neurite outgrowth. If an antibody to a
15 neurite growth regulatory factor is available, a neurite
growth regulatory factor protein may be identified by binding
of labeled antibody to the putatively neurite growth
regulatory factor-synthesizing clones, in an ELISA (enzyme-
linked immunosorbent assay)-type procedure.

20   In specific embodiments, transformation of host
cells with recombinant DNA molecules that incorporate an
isolated neurite growth regulatory factor gene, cDNA, or
synthesized DNA sequence enables generation of multiple copies
of.the gene.· Thus, the gene may be obtained in large
25 quantities by growing transformants, isolating the recombinant
DNA molecules from the transformants and, when necessary,
retrieving the inserted gene from the isolated recombinant
DNA.

If the ultimate goal is to insert the gene into
30 virus expression vectors such as vaccinia virus or adenovirus,
the recombinant DNA molecule that incorporates a neurite
growth regulatory factor gene can be modified so that the gene
is flanked by virus sequences that allow for genetic
recombination in cells infected with the virus so that the
35 gene can be inserted into the viral genome.

After the neurite growth regulatory factor DNA-containing clone has been identified, grown, and harvested, its DNA insert may be characterized as described in Section 5.3.4, _infra_. When the genetic structure of a neurite growth

5 regulatory factor gene is known, it is possible to manipulate the structure for optimal use in the present invention. For example, promoter DNA may be ligated 5' of a neurite growth regulatory factor coding sequence, in addition to or replacement of the native promoter to provide for increased

10 expression of the protein. Many manipulations are possible, and within the scope of the present invention.

5.3.2. EXPRESSION OF THE CLONED NEURITE GROWTH REGULATORY FACTOR GENES

15 The nucleotide sequence coding for a neurite growth regulatory factor protein or a portion thereof, can be inserted into an appropriate expression vector, _i.e._, a vector which contains the necessary elements for the transcription and translation of the inserted protein-coding sequence. The

20 necessary transcriptional and translation signals can also be supplied by the native neurite growth regulatory factor gene and/or its flanking regions. A variety of host-vector systems may be utilized to express the protein-coding sequence. These include but are not limited to mammalian cell systems infected

25 with virus (_e.g._, vaccinia virus, adenovirus, etc.); insect cell systems infected with virus (_e.g._, baculovirus); microorganisms such as yeast containing yeast vectors, or bacteria transformed with bacteriophage DNA, plasmid DNA, or cosmid DNA. The expression elements of these vectors vary in

30 their strengths and specificities. Depending on the host-vector system utilized, any one of a number of suitable transcription and translation elements may be used.

Any of the methods previously described for the insertion of DNA fragments into a vector may be used to

35 construct expression vectors containing a chimeric gene consisting of appropriate transcriptional/translational

control signals and the protein coding sequences. These
methods may include _in_ _vitro_ recombinant DNA and synthetic
techniques and _in_ _vivo_ recombinations (genetic recombination).

5   Expression vectors containing neurite growth regulatory
factor gene inserts can be identified by three general
approaches: (a) DNA-DNA hybridization, (b) presence or
absence of "marker" gene functions, and (c) expression of
inserted sequences. In the first approach, the presence of a
foreign gene inserted in an expression vector can be detected
10 by DNA-DNA hybridization using probes comprising sequences
that are homologous to an inserted neurite growth regulatory
factor gene. In the second approach, the recombinant
vector/host system can be identified and selected based upon
the presence or absence of certain "marker" gene functions
15 (_e.g._, thymidine kinase activity, resistance to antibiotics,
transformation phenotype, occlusion body formation in
baculovirus, etc.) caused by the insertion of foreign genes in
the vector. For example, if a given neurite growth regulatory
factor gene is inserted within the marker gene sequence of the
20 vector, recombinants containing the neurite growth regulatory
factor insert can be identified by the absence of the marker
gene function. In the third approach, recombinant expression
vectors can be identified by assaying the foreign gene product
expressed by the recombinant. Such assays can be based on the
25 physical, immunological, or functional properties of a given
neurite growth regulatory factor gene product.

Once a particular recombinant DNA molecule is identified
and isolated, several methods known in the art may be used to
propagate it. Once a suitable host system and growth
30 conditions are established, recombinant expression vectors can
be propagated and prepared in quantity. As previously
explained, the expression vectors which can be used include,
but are not limited to, the following vectors or their
derivatives: human or animal viruses such as vaccinia virus

35

or adenovirus; insect viruses such as baculovirus; yeast vectors; bacteriophage vectors (e.g., lambda), and plasmid and cosmid DNA vectors, to name but a few.

In addition, a host cell strain may be chosen which
5   modulates the expression of the inserted sequences, or modifies and processes the gene product in the specific fashion desired. Expression from certain promoters can be elevated in the presence of certain inducers; thus, expression of the genetically engineered neurite growth regulatory factor
10   protein may be controlled. Furthermore, different host cells have characteristic and specific mechanisms for the translational and post-translational processing and modification (e.g., glycosylation, cleavage) of proteins. Appropriate cell lines or host systems can be chosen to ensure
15   the desired modification and processing of the foreign protein expressed. For example, expression in a bacterial system can be used to produce an unglycosylated core protein product. Expression in yeast will produce a glycosylated product. Expression in mammalian (e.g. COS) cells can be used to ensure
20   "native" glycosylation of the heterologous neurite growth regulatory factor protein. Furthermore, different vector/host expression systems may effect processing reactions such as proteolytic cleavages to different extents.

25   5.3.3.   IDENTIFICATION AND PURIFICATION OF
                          THE EXPRESSED GENE PRODUCT
              Once a recombinant which expresses a given neurite growth regulatory factor gene is identified, the gene product can be purified as described in Section 5.1, supra, and
30   analyzed as described in Section 5.2, supra.
              The amino acid sequence of a given neurite growth regulatory factor protein can be deduced from the nucleotide sequence of the cloned gene, allowing the protein, or a fragment thereof, to be synthesized by standard chemical
35   methods known in the art (e.g., see Hunkapiller, et al., 1984, Nature 310:105-111).

In particular embodiments of the present invention, such neurite growth regulatory factor proteins, whether produced by recombinant DNA techniques or by chemical synthetic methods, include but are not limited to those

5   containing altered sequences in which functionally equivalent amino acid residues are substituted for residues within the sequence resulting in a silent change. For example, one or more amino acid residues within the sequence can be substituted by another amino acid of a similar polarity which

10   acts as a functional equivalent, resulting in a silent alteration. Substitutes for an amino acid within the sequence may be selected from other members of the class to which the amino acid belongs. For example, the nonpolar (hydrophobic) amino acids include alanine, leucine, isoleucine, valine,

15   proline, phenylalanine, tryptophan, and methionine. The polar neutral amino acids include glycine, serine, threonine, cysteine, tyrosine, asparagine, and glutamine. The positively charged (basic) amino acids include arginine, lysine, and histidine. The negatively charged (acidic) amino acids

20   include aspartic acid and glutamic acid. Also included within the scope of the invention are neurite growth regulatory factor proteins which are differentially modified during or after translation, e.g., by glycosylation, proteolytic cleavage, etc.

25

5.3.4. CHARACTERIZATION OF THE NEURITE, GROWTH REGULATORY FACTOR GENES

The structure of a given neurite growth regulatory factor gene can be analyzed by various methods known in the art.

30

The cloned DNA or cDNA corresponding to a given neurite growth regulatory factor gene can be analyzed by methods including but not limited to Southern hybridization (Southern, 1975, J. Mol. Biol. 98:503-517), Northern

35   hybridization (Alwine, et al., 1977, Proc. Natl. Acad. Sci. U.S.A. 74:5350-5354; Wahl, et al., 1987, Meth. Enzymol. 152:572-581), restriction endonuclease mapping (Maniatis, et

al., 1982, Molecular Cloning, A Laboratory Manual, Cold Spring
Harbor Laboratory, Cold Spring Harbor, New York), and DNA
sequence analysis.

DNA sequence analysis can be performed by any
5 techniques known in the art including but not limited to the
method of Maxam and Gilbert (1980, Meth. Enzymol. 65:499-560),
the Sanger dideoxy method (Sanger, et al., 1977, Proc. Natl.
Acad. Sci. U.S.A. 74:5463-5467), or use of an automated DNA
sequenator (e.g., Applied Biosystems, Foster City, CA).
10

5.4. PRODUCTION OF ANTIBODIES TO NEURITE, GROWTH REGULATORY FACTORS

Antibodies can be produced which recognize neurite
growth regulatory factors or related proteins. Such
15 antibodies can be polyclonal or monoclonal.

Various procedures known in the art may be used for
the production of polyclonal antibodies to epitopes of a given
neurite growth regulatory factor. For the production of
antibody, various host animals can be immunized by injection
20 with a neurite growth regulatory factor protein, or a
synthetic protein, or fragment thereof, including but not
limited to rabbits, mice, rats, etc. Various adjuvants may be
used to increase the immunological response, depending on the
host species, and including but not limited to Freund's
25 (complete and incomplete), mineral gels such as aluminum
hydroxide, surface active substances such as lysolecithin,
pluronic polyols, polyanions, peptides, oil emulsions, keyhole
limpet hemocyanins, dinitrophenol, and potentially useful
human adjuvants such as BCG (bacille Calmette-Guerin) and
30 corynebacterium parvum.

A monoclonal antibody to an epitope of a neurite
growth regulatory factor can be prepared by using any
technique which provides for the production of antibody
molecules by continuous cell lines in culture. These include
35 but are not limited to the hybridoma technique originally
described by Kohler and Milstein (1975, Nature 256:495-497),
and the more recent human B cell hybridoma technique (Kozbor

et al., 1983, Immunology Today 4:72) and EBV-hybridoma
technique (Cole et al., 1985, Monoclonal Antibodies and Cancer
Therapy, Alan R. Liss, Inc., pp. 77-96). In a particular
embodiment, the procedure described _infra_ in Section 8.1. may
5   be used to obtain mouse monoclonal antibodies which recognize
the 35 kD and 250 kD CNS myelin associated inhibitory
proteins.

The monoclonal antibodies for therapeutic use may
be human monoclonal antibodies or chimeric human-mouse (or
10 other species) monoclonal antibodies. Human monoclonal
antibodies may be made by any of numerous techniques known in
the art (_e.g._, Teng et al., 1983, Proc. Natl. Acad. Sci.
U.S.A. 80:7308-7312; Kozbor et al., 1983, Immunology Today
4:72-79; Olsson et al., 1982, Meth. Enzymol. 92:3-16).
15 Chimeric antibody molecules may be prepared containing a mouse
antigen-binding domain with human constant regions (Morrison
et al., 1984, Proc. Natl. Acad. Sci. U.S.A. 81:6851, Takeda et
al., 1985, Nature 314:452).

A molecular clone of an antibody to a neurite
20 growth regulatory factor epitope can be prepared by known
techniques. Recombinant DNA methodology (see e.g., Maniatis
et al., 1982, Molecular Cloning, A Laboratory Manual, Cold
Spring Harbor Laboratory, Cold Spring Harbor, New York) may be
used to construct nucleic acid sequences which encode a
25 monoclonal antibody molecule, or antigen binding region
thereof.

Antibody molecules may be purified by known
techniques, _e.g._, immunoabsorption or immunoaffinity
chromatography, chromatographic methods such as HPLC (high
30 performance liquid chromatography), or a combination thereof,
etc.

Antibody fragments which contain the idiotype of
the molecule can be generated by known techniques. For
example, such fragments include but are not limited to: the
35 $F(ab')_2$ fragment which can be produced by pepsin digestion of
the antibody molecule; the Fab' fragments which can be

generated by reducing the disulfide bridges of the $F(ab')_2$ fragment, and the 2 Fab or Fab fragments which can be generated by treating the antibody molecule with papain and a reducing agent.

5.5. NEURITE GROWTH REGULATORY FACTOR-RELATED DERIVATIVES, ANALOGS, AND PEPTIDES

The production and use of derivatives, analogs, and peptides related to a given neurite growth regulatory factor are also envisioned, and within the scope of the present invention and include molecules antagonistic to neurite growth regulatory factors (for example, and not by way of limitation, anti-idiotype antibodies). Such derivatives, analogs, or peptides which have the desired inhibitory activity can be used, for example, in the treatment of neuroblastoma (see Section 5.6, _infra_). Derivatives, analogs, or peptides related to a neurite growth regulatory factor can be tested for the desired activity by assays for nonpermissive substrate effects. For example, procedures such as the assay for nonpermissiveness in which the effect of the various translation products on the spreading of 3T3 cells on a polylysine coated tissue culture dish is observed (see Caroni and Schwab, 1988, J. Cell Biol. 106:1281).

The neurite growth regulatory factor-related derivatives, analogs, and peptides of the invention can be produced by various methods known in the art. The manipulations which result in their production can occur at the gene or protein level. For example, a cloned neurite growth regulatory factor gene can be modified by any of numerous strategies known in the art (Maniatis, et al., 1982, Molecular Cloning, A Laboratory Manual, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York). A given neurite growth regulatory factor sequence can be cleaved at appropriate sites with restriction endonuclease(s), subjected to enzymatic modifications if desired, isolated, and ligated _in vitro_. In the production of a gene encoding a derivative, analogue, or peptide related to a neurite growth regulatory

factor, care should be taken to ensure that the modified gene remains within the same translational reading frame as the neurite growth regulatory factor, uninterrupted by translational stop signals, in the gene region where the
5 desired neurite growth regulatory factor-specific activity is encoded.

Additionally, a given neurite growth regulatory factor gene can be mutated in vitro or in vivo, to create and/or destroy translation, initiation, and/or termination
10 sequences, or to create variations in coding regions and/or form new restriction endonuclease sites or destroy preexisting ones, to facilitate further in vitro modification. Any technique for mutagenesis known in the art can be used, including but not limited to, in vitro site-directed
15 mutagenesis (Hutchinson, et al., 1978, J. Biol. Chem. 253:6551), use of TAB® linkers (Pharmacia), etc.

5.6.   USES OF NEURITE GROWTH REGULATORY FACTORS

5.6.1.   DIAGNOSTIC USES
20

5.6.1.1.   CNS MYELIN ASSOCIATED INHIBITORY PROTEINS

CNS myelin associated inhibitory proteins, analogs, derivatives, and subsequences thereof, and anti-inhibitory protein antibodies have uses in diagnostics. Such molecules
25 can be used in assays such as immunoassays to detect, prognose, diagnose, or monitor various conditions, diseases, and disorders affecting neurite growth extension, invasiveness, and regeneration. In one embodiment of the invention, these molecules may be used for the diagnosis of
30 malignancies. Alternatively, the CNS myelin associated inhibitory proteins, analogs, derivatives, and subsequences thereof may be used to monitor therapies for diseases and conditions which ultimately result in nerve damage; such diseases and conditions include but are not limited to CNS
35 trauma, (e.g. spinal cord injuries), infarction, infection, malignancy, exposure to toxic agents, nutritional deficiency,

paraneoplastic syndromes, and degenerative nerve diseases
(including but not limited to Alzheimer's disease, Parkinson's
disease, Huntington's Chorea, amyotrophic lateral sclerosis,
and progressive supra-nuclear palsy). In a specific

5   embodiment, such molecules may be used to detect an increase
in neurite outgrowth as an indicator of CNS fiber
regeneration.

For example, in specific embodiments, the absence of the
CNS myelin associated inhibitory proteins in a patient sample

10   containing CNS myelin can be a diagnostic marker for the
presence of a malignancy, including but not limited to
glioblastoma, neuroblastoma, and melanoma, or a condition
involving nerve growth, invasiveness, or regeneration in a
patient. In a particular embodiment, the absence of the

15   inhibitory proteins can be detected by means of an immunoassay
in which the lack of any binding to anti-inhibitory protein
antibodies (e.g., IN-1, IN-2) is observed.

The immunoassays which can be used include but are not
limited to competitive and non-competitive assay systems using

20   techniques such as radioimmunoassays, ELISA (enzyme linked
immunosorbent assay), "sandwich" immunoassays, precipitation
reactions, gel diffusion precipitation reactions,
immunodiffusion assays, agglutination assays, complement-
fixation assays, immunoradiometric assays, fluorescent

25   immunoassays, protein A immunoassays, immunoelectrophoresis
assays, and immunohistochemistry on tissue sections, to name
but a few.

In a specific embodiment, ligands which bind to a CNS
myelin associated inhibitory protein can be used in imaging

30   techniques. For example, small peptides (e.g., inhibitory
protein receptor fragments) which bind to the inhibitory
proteins, and which are able to penetrate through the blood-
brain barrier, when labeled appropriately, can be used for
imaging techniques such as PET (positron emission tomography)

35   diagnosis or scintigraphy detection, under conditions
noninvasive to the patient.

Neurite growth inhibitory factor genes, DNA, cDNA, and
RNA, and related nucleic acid sequences and subsequences,
including complementary sequences, can also be used in
hybridization assays. The neurite growth inhibitory factor
5   nucleic acid sequences, or subsequences thereof comprising
about at least 15 nucleotides, can be used as hybridization
probes. Hybridization assays can be used to detect, prognose,
diagnose, or monitor conditions, disorders, or disease states
associated with changes in neurite growth inhibitory factor
10 expression as described _supra_. For example, total RNA in
myelin, e.g., on biopsy tissue sections, from a patient can be
assayed for the presence of neurite growth inhibitory factor
mRNA, where the amount of neurite growth inhibitory factor
mRNA is indicative of the level of inhibition of neurite
15 outgrowth activity in a given patient.

5.6.1.2.   CNS MYELIN ASSOCIATED
INHIBITORY PROTEIN RECEPTORS

CNS myelin associated inhibitory protein receptors
20 as well as analogs, derivatives, and subsequences thereof, and
anti-receptor antibodies have uses in diagnostics. These
molecules of the invention can be used in assays such as
immunoassays or binding assays to detect, prognose, diagnose,
or monitor various conditions, diseases, and disorders
25 affecting neurite growth, extension, invasion, and
regeneration. For example, it is possible that a lower level
of expression of these receptors may be detected in various
disorders associated with enhanced neurite invasiveness or
regeneration such as those involving nerve damage, infarction,
30 degenerative nerve diseases, or malignancies. The CNS myelin
associated inhibitory protein receptors, analogs, derivatives,
and subsequences thereof may also be used to monitor therapies
for diseases and disorders which ultimately result in nerve
damage, which include but are not limited to CNS trauma (e.g.
35 spinal cord injuries), stroke, degenerative nerve diseases,
and for malignancies.

The assays which can be used include but are not limited to those described _supra_ in Section 5.6.1.1.

Neurite growth inhibitory factor receptor genes and related nucleic acid sequences and subsequences, including

5 complementary sequences, can also be used in hybridization assays, to detect, prognose, diagnose, or monitor conditions, disorders, or disease states associated with changes in neurite growth inhibitory factor receptor expression.

10   5.6.1.3.   METALLOPROTEASES AND THEIR INHIBITORS

The metalloproteases of the invention, and their analogs, derivatives, and fragments thereof, as well as inhibitors and anti-metalloprotease antibodies, may be used for diagnostic purposes. These molecules of the invention may

15 be used in assays such as immunoassays or inhibition type assays to detect, prognose, diagnose, or monitor various conditions, diseases, and disorders affecting neurite growth extension, invasiveness, or regeneration. In a specific embodiment, the molecules of the present invention can be used

20 to diagnose malignant tumors, in particular, those capable of metastasizing to the brain, (e.g., glioblastoma) by detecting the presence of or an increase in metalloprotease levels. Alternatively, the molecules of the present invention may be used to monitor therapies for malignant tumors such as

25 glioblastoma by detecting changes in metalloprotease levels. In this latter embodiment, decreases or the disappearance of metalloprotease levels should can be indicative of treatment efficacy.

The assays which can be used include but are not

30 limited to those described _supra_ in Section 5.6.1.1.

Metalloprotease genes and related nucleic acid sequences and subsequences, including complementary sequences, can also be used in hybridization assays, to detect, prognose, diagnose, or monitor conditions, disorders, or disease states

35 associated with changes in metalloprotease expression as described _supra_. For example, total RNA in a sample (e.g.,

glial cells) from a patient can be assayed for the presence of metalloprotease mRNA, where the presence or amount of · metalloprotease mRNA is indicative of a malignancy in the patient. In particular, a malignancy that can be metastatic

5 to the brain (e.g., glioblastoma) can be detected.

5.6.2. THERAPEUTIC USES

5.6.2.1.   CNS MYELIN ASSOCIATED INHIBITORY PROTEINS

10   CNS myelin associated inhibitory proteins of the present invention can be therapeutically useful in the treatment of patients with malignant tumors including, but not limited to melanoma or tumors of nerve tissue (e.g. neuroblastoma). In one embodiment, patients with

15 neuroblastoma can be treated with the 35 kD and/or 250 kD proteins or analogs, derivatives, or subsequences thereof, and the human functional equivalents thereof, which are inhibitors of neurite extension. In another embodiment, a patient can be therapeutically administered both a CNS myelin-associated

20 inhibitory protein and a metalloprotease inhibitor.

       In an alternative embodiment, derivatives, analogs, or subsequences of CNS myelin inhibitory proteins which inhibit the native inhibitory protein function can be used in regimens where an increase in neurite extension, growth, or

25 regeneration is desired, e.g., in patients with nerve damage. Patients suffering from traumatic disorders (including but not limited to spinal cord injuries, spinal cord lesions, or other CNS pathway lesions), surgical nerve lesions, damage secondary to infarction, infection, exposure to toxic agents,

30 malignancy, paraneoplastic syndromes, or patients with various types of degenerative disorders of the central nervous system (Cutler, 1987, In: Scientific American Medicines v. 2, Scientific American Inc., NY, pp. 11-1-11-13) can be treated with such inhibitory protein antagonists. Examples of such

35 disorders include but are not limited to Alzheimer's Disease, Parkinsons' Disease, Huntington's Chorea, amyotrophic lateral

sclerosis, or progressive supranuclear palsy. Such antagonists may be used to promote the regeneration of CNS pathways, fiber systems and tracts. Administration of antibodies directed to an epitope of CNS myelin associated

5   inhibitory proteins such as the 35 kD and/or 250 kD proteins, (or the binding portion thereof, or cells secreting such as antibodies) can also be used to inhibit 35 kD and/or 250 kD protein function in patients. In a particular embodiment of the invention, antibodies directed to the 35 kD and/or 250 kD

10   myelin associated inhibitory protein may be used to promote the regeneration of nerve fibers over long distances following spinal cord damage; in a specific example, monoclonal antibody IN-1 may be used.

Various delivery systems are known and can be used

15   for delivery of CNS myelin inhibitory proteins, related molecules, or antibodies thereto, e.g., encapsulation in liposomes or semipermeable membranes, expression by bacteria, etc. Linkage to ligands such as antibodies can be used to target myelin associated protein-related molecules to

20   therapeutically desirable sites in vivo. Methods of introduction include but are not limited to intradermal, intramuscular, intraperitoneal, intravenous, subcutaneous, oral, and intranasal routes, and infusion into ventricles or a site of tumor removal. Likewise, cells secreting CNS myelin

25   inhibitory protein antagonist activity, for example, and not by way of limitation, hybridoma cells, encapsulated in a suitable biological membrane may be implanted in a patient so as to provide a continuous source of anti-CNS myelin inhibiting protein antibodies.

30   In addition, any method which results in decreased synthesis of CNS myelin inhibitory proteins may be used to diminish their biological function. For example, and not by way of limitation, agents toxic to the cells which synthesize CNS myelin inhibitory proteins (e.g. oligodendrocytes) may be

35   used to decrease the concentration of inhibitory proteins to promote regeneration of neurons.

5.6.2.2.   CNS MYELIN ASSOCIATED INHIBITORY PROTEIN RECEPTORS

CNS myelin associated inhibitory protein receptors or fragments thereof, and antibodies thereto, can be therapeutically useful in the treatment of patients with nerve damage including but not limited to that resulting from CNS trauma (e.g., spinal cord injuries), infarction, or degenerative disorders of the central nervous system which include but are not limited to Alzheimer's disease, Parkinson's disease, Huntington's Chorea, amyotrophic lateral sclerosis, or progressive supranuclear palsy. For example, in one embodiment, CNS myelin associated inhibitory protein receptors, or subsequences or analogs thereof which contain the inhibitory protein binding site, can be administered to a patient to "compete out" binding of the inhibitory proteins to their natural receptor, and to thus promote nerve growth or regeneration in the patient. In an alternative embodiment, antibodies to the inhibitory protein receptor (or the binding portion thereof or cells secreting antibodies binding to the receptor) can be administered to a patient in order to prevent receptor function and thus promote nerve growth or regeneration in the patient. Patients in whom such a therapy may be desired include but are not limited to those with nerve damage, stroke, or degenerative disorders of the central nervous system as described supra.

Various delivery systems are known and can be used for delivery of CNS myelin associated inhibitory protein receptors, related molecules, or antibodies thereto, e.g., encapsulation in liposomes, expression by bacteria, etc. Linkage to ligands such as antibodies can be used to target myelin associated protein receptor-related molecules to therapeutically desirable sites in vivo. Methods of introduction include but are not limited to intradermal, intramuscular, intraperitoneal, intravenous, subcutaneous, oral, intranasal routes, and infusion into ventricles or a site of tumor removal.

5.6.2.3. METALLOPROTEASES AND THEIR INHIBITORS

The metalloproteases of the present invention can be therapeutically useful in the treatment of various types of nerve damage or degenerative disorders of the central nervous system (such as those described _supra_, Section 5.6.2.2) In one embodiment, patients suffering from nerve damage resulting from trauma, stroke, or neurodegenerative disorders can be treated with the metalloprotease or proteolytically active analogs, derivatives, or subsequences thereof which stimulate neurite extension or regeneration of CNS fiber.

In an alternative embodiment, derivatives, analogs, or subsequences of the metalloproteases which antagonize or inhibit metalloprotease function, or chemical inhibitors of the metalloprotease activity, can be used in regimens where an inhibition of invasive migration and spread in the CNS is desired. Such inhibitors may include but are not limited to 1,10 phenanthroline, EDTA, EGTA, cbz-tyr-tyr, cbz-gly-phe-NH_2, cbz-phe-phe-NH_2, and cbz-gly-phe-phe-NH_2. 1,10 phenanthroline, EDTA, and EGTA may be obtained from commercial vendors (e.g. Sigma Chemical Co.). Cbz-tyr-tyr, cbz-gly-phe-NH_2, cbz-phe-phe-NH_2, and cbz-gly-phe-phe-NH_2 may also be obtained from commercial vendors (e.g. Vega Biotechnologies), or may be chemically synthesized. In specific embodiments, patients with various types of malignant tumors, in particular, those metastatic to the brain, can be treated with such inhibitors. In a preferred embodiment, a patient with a glioblastoma can be treated with such inhibitors. In another specific embodiment, administration of antibodies directed to an epitope of the metalloprotease can also be used to inhibit metalloprotease function in patients. In yet another specific embodiment of the invention, metalloprotease inhibitors and a CNS myelin associated inhibitory protein can both be administered to a patient for the treatment of a malignant tumor, examples of which include but are not limited to glioblastoma, neuroblastoma, or a melanoma.

Various delivery systems are known and can be used for the delivery of metalloproteases and related molecules, e.g., encapsulation in liposomes or semipermeable membranes, expression by bacteria, etc. Linkage to ligands such as

5 antibodies can be used to target molecules to therapeutically desirable sites in vivo. Methods of introduction include but are not limited to intradermal, intramuscular, intraperitoneal, intravenous, subcutaneous, oral, and intranasal routes, and infusion into ventricles or a site of

10 tumor removal.

6. OLIGODENDROCYTES AND CNS MYELIN ARE NON-
    PERMISSIVE SUBSTRATES FOR NEURITE GROWTH
    AND FIBROBLAST SPREADING IN VITRO

To study the interaction of neurons with central

15 nervous system (CNS) glial cells, dissociated sympathetic or sensory ganglion cells or fetal retinal cells were plated onto cultures of dissociated optic nerve glial cells of young rats. Whereas astrocytes favored neuron adhesion and neurite outgrowth, oligodendrocytes differed markedly in

20 their properties as neuronal substrates. Immature (O_4^+, $A_2B_5^+$, $GalC^-$), oligodendrocytes were frequently contacted by neurons and neurites. In contrast, differentiated oligodendrocytes (O_4^+, $A_2B_5^-$, $GalC^+$) represented a non-permissive substrate for neuronal adhesion and neurite

25 growth. When neuroblastoma cells or 3T3 fibroblasts were plated into optic nerve glial cultures, the same differences were observed; differentiated oligodendrocytes were non-permissive for cell adhesion, neurite growth, or fibroblast spreading. These nonpermissive oligodendrocytes were

30 characterized by a radial, highly branched process network, often contained myelin basic protein (MBP), and may, therefore, correspond to cells actively involved in the production of myelin-like membranes.

Isolated myelin from adult rat spinal cord was

35 adsorbed to polylysine coated culture dishes and tested as substrate for peripheral neurons, neuroblastoma cells, or

3T3 cells. Again, cell attachment, neurite outgrowth, and
fibroblast spreading was strongly impaired. General
physico-chemical properties of myelin were not responsible
for this effect, since myelin from rat sciatic nerves
5   favored neuron adhesion and neurite growth as well as
spreading of 3T3 cells. These results show that
differentiated oligodendrocytes express non-permissive
substrate properties, which may be of importance in CNS
development or regeneration.

10

6.1. MATERIALS AND METHODS

6.1.1. GLIAL CELL CULTURES

Optic nerves were dissected from 7-12 day old or
15   young adult (180 - 220 g) Wistar rats and collected in
plating medium (air-buffered enriched L_{15} with 5% rat serum;
Mains and Patterson, 1973, J. Cell Biol. 59:329-345). The
meninges and blood vessels were carefully removed under a
microscope and the nerves were cut into small pieces.
20   Dissociation of 10 day old nerves was done for 25 minutes
twice in 0.25% trypsin (Sigma) and 0.02% collagenase
(Worthington) (Raff et al., 1979, Brain Res. 174:283-318) in
CMF-PBS (Ca^{++}/Mg^{++} - free phosphate buffered saline) at
37°C. Adult optic nerves were dissociated in 0.1% trypsin,
25   0.1% collagenase for 1 hour at 37°C followed by 0.5% trypsin
for 10 minutes. After washing and dissociation by
trituration with a Pasteur pipet, the cells were plated into
the wells of 35 mm tissue culture dishes containing four
internal wells at a density of 20,000 to 30,000 cells per
30   well (surface of well: 95 mm^2). For 7 - 10 day old optic
nerves the yield of the dissociation was about 10,000 cells
per nerve. The culture substrate for most of the
experiments was polyornithine (PORN, Sigma, 0.5 mg/ml in
borate buffer, incubated overnight) or polylysine (PLYS,
35   Sigma, 50 ng/ml in water); in some experiments, a dried
collagen film (calf skin collagen, incubation overnight with

sterile solution), laminin-coated PORN (purified mouse EHS
tumor laminin (5 ng/ml, incubated for 3 hours on dishes
previously coated with PORN), or plain tissue culture
plastic was used. The culture medium was an enriched L_{15}
5   medium with 5% rat serum, penicillin (100 U/ml) and
streptomycin (100 ng/ml) (Mains and Patterson, 1973, J. Cell
Biol. 59:329-345). In some experiments, 10% fetal calf
serum (FCS) was added instead of the rat serum.

            Optic nerves of E13 or E17 chicken embryos were
10   dissociated by brief trypsin/collagenase treatment and
cultured for 2 - 7 days in L_{15} with 5% FCS on PORN-coated
culture dishes.

            6.1.2.   GLIA - NERVE CELL CO-CULTURES
15   Three different types of nerve cells were co-
cultured with glial cells: sympathetic neurons from the
superior cervical ganglion of newborn rats, sensory neurons
from dorsal root ganglia of newborn rats, or cells from the
retina of E17-E18 embryonic rats. Superior cervical and
20   dorsal root ganglia were dissected and dissociated into
single cells as described (Mains and Patterson, 1973, J.
Cell Biol. 59:329-345; Schwab and Thoenen, 1985, J.
Neurosci. 5:2415-2423). Retinas were dissected from the
embryos, cleaned from adhering blood vessels and incubated
25   in 0.03% trypsin, 0.03% DNase for 10 minutes at 37°C, washed
by centrifugation in serum-containing medium and dissociated
by trituration.

            The neurons were added to 2 - 10 day old glial
cultures in the same medium, with the addition of NGF (2.5S
30   NGF, 50 or 100 ng/ml) for sensory and sympathetic neurons or
brain-derived neurotrophic factor for the retinal cells
(Johnson, J.E. et al., 1986, J. Neurosci. 6:3031-3038). In
order to suppress the growth of Schwann cells added together
with the peripheral neurons, pulses of cytosine arabinoside
35   (Ara C, 10^{-5} M) were given twice for 24 hours on the 2nd and
5th day of co-culture in some experiments. The cultures

were processed for antibody staining after 1 - 5 days of co-culture in the case of retina cells, or after 2 days to 3 weeks in the case of peripheral ganglion cells.

5 Mouse <u>neuroblastoma cells</u> (line NB-2A) cultured in DMEM/10% FCS were detached from the culture flasks by a brief treatment with 0.1% trypsin in CMF-Hank's solution terminated by addition of DMEM/FCS. After washing, the cells were added to glial cultures (40,000 or 20,000 cells per well) in DMEM/FCS with either 2 mM dibutyryl-cyclic AMP 10 or glia-derived neurite promoting factor (GdNPF; Guenther et al., 1986, EMBO J. 4:1963-1966).

Mouse NIH 3T3 <u>cells</u>, treated identically to the neuroblastoma cells, were added to 2 - 3 day old cultures of 7 day old or newborn rat optic nerves at a concentration of 15 20,000 or 40,000 cells per well in DMEM containing 10% fetal calf serum or in MEM supplied with insulin (20 ng/ml) and transferrin (50 ng/ml). Cultures were returned to the incubator for 2 - 4 hours and then fixed with warm 4% formalin in phosphate buffer and double stained with the O_1 20 and O_4 antibodies.

6.1.3.   IMMUNOFLUORESCENCE

The following antibodies as markers for oligodendrocytes, astrocytes, neurons or fibroblasts were 25 used: <u>oligodendrocytes</u>: mouse monoclonal antibody (mAB) O_4 (Sommer and Schachner, 1981, Dev. Biol. 83:311-327); mouse mAB O_1 (Sommer and Schachner, 1981, Dev. Biol. 83:311-327); specific for galactocerebroside (GalC; Singh and Pfeiffer, 1985, J. Neurochem. 45:1371-1381); goat antiserum against 30 myelin basic protein of rabbits (Omlin, et al., 1982, J. Cell Biol. 95:242-248). <u>Precursor cells</u>: mouse mAB A_2B_5 (Sera-Lab, Crawley Down, GB). <u>Astrocytes</u>: rabbit antiserum agaist glial fibrillary acid protein (GFAP) (Dahl and Bignami, 1976, Brain Res. 116:150-157). <u>Neurons</u>: mouse mAB 35 against guinea pig or rabbit neurofilaments (Willard and

Simon, 1981, J. Cell Biol. 89:198-205). <u>Fibroblasts</u>: mouse
mAB Ox7 against Thy-1.1 (Sera-Lab); goat antiserum against
human fibronectin (LETS protein; Cappel, NC).

5   The specific antibodies were visualized by the
corresponding anti-mouse, anti-rabbit or anti-goat -
fluorescein isothiocyanate (FITC) or - rhodamine
isothiocyanate (RITC) linked secondary antibodies (Cappel,
NC). Prior to staining, the cultures were washed twice with
PBS containing 5% sucrose and 0.1% bovine serum albumin
10   (BSA). The antibodies O_1, O_4 and A_2B_5 were directed against
surface antigens and were therefore incubated on the living
cultures at room temperature for 30 minutes at a dilution of
1:20 in PBS/sucrose/BSA. Antibodies against Thy-1 were
diluted 1:10, anti-fibronectin 1:20. The cultures were then
15   rinsed twice, fixed for 10 minutes with 4% formalin in PBS,
rinsed again, incubated for 1 hour with the labeled
secondary antibodies (dilution 1:30 to 1:100), washed and
mounted in PBS:glycerol (1:1). - For visualization of myelin
basic protein (MBP) the cultures were briefly fixed in 4%
20   formalin, then treated with ethanol/acetic acid and finally
incubated with anti-MBP antiserum (1:500 dilution) for 1
hour at room temperature. Ethanol/acetic acid fixation was
also used for visualization of neurofilaments. For double
labeling experiments of A_2B_5 or O_1 antibodies with the O_4
25   antibody, living cultures were first incubated with
antibodies A_2B_5 or O_1 followed by anti-mouse-FITC, and then
with antibody O_4 antigen; the sequence was reversed in some
experiments. Staining the GFAP was done on cultures
previously fixed in 95% ethanol/5% acetic acid for 30
30   minutes at 4°C and rehydrated into PBS. In the case of
O_4/GFAP double-labeling experiments, staining was first done
with the O_4 antibody on the living cultures followed by 10
minutes fixation in 4% formalin, subsequent ethanol/acetic
acid treatment and GFAP-staining. For visualization of MBP,
35   the clutures were briefly fixed in 4% formalin, then treated
with ethanol/acetic acid and finally incubated with anti-MBP

antiserum (1:500) for one hour at room temperature. Ethanol/acetic acid fixation was also used for visualization of neurofilaments.

5   Double-labeled cultures were evaluated by systematically screening in the fluorescence microscope for the presence of one antigen (usually O_4), and every labeled cell was examined for the presence of the other antigen, e.g. A_2B_5, O_1, or GFAP.

10   6.1.4.   EVALUATION OF CO-CULTURES WITH NERVE
                     CELLS, NEUROBLASTOMA CELLS, OR 3T3 CELLS
       Antibody-labeled cultures were systematically screened in the fluorescence microscope and all O_4-labeled cells were photographed. The same fields were photographed under phase contrast illumination. The oligodendrocyte

15   surface area occupied by or in contact with neurons, neurites, ganglionic Schwann cells, or 3T3 cells was estimated and the oligodendrocytes were grouped into 3 categories: cells with < 20%, 20% - 80%, or > 80% of the territory covered by neurons, neurites or 3T3 cells. Single

20   thin processes, especially of immature cells, were often excluded from the evaluation for reason of comparability with the dense process network of highly branched oligodendrocytes. In experiments with retinal cells, total oligodendrocyte territory and areas overlapped by retinal

25   cells were measured with a Hewlett-Packard digitizer. The oligodendrocyte subtypes were identified on the corresponding fluorescence micrographs. The criteria used for identification were cell morphology and antigenic characteristics (O_4/O_1). A_2B_5-staining could not be used as

30   a marker for immature cells, since this antigen was rapidly lost (without a concomitant change in cell morphology); after coculture with neurons. The distinguishing morphological criteria were: shape and size of the cell

35   body, number of primary processes, branching pattern of processed, and the occurrence of anastomoses and membrane sheets within the process network. With these criteria,

<u>highly</u> <u>branched</u> <u>oligodendrocytes</u> <u>and</u> <u>immature</u>
<u>oligodendrocytes</u> could be reproducibly distinguished. Most
(but not all) of the highly branched cells were positive for
the O_1 antigen; immature cells were consistently negative.

5   Quantification of the direction of neuroblastoma
process outgrowth with respect to highly branched
oligodendrocytes was done as illustrated in Figure 5.
Highly branched oligodendrocytes were sampled
systematically, and neighbouring neuroblastoma cells were

10 classified as "adjacent" if the distance between the edge of
the oligodendrocyte process network and the NB-2A cell was
less than 2 cell body diameters. Further cells were
classified as "distant" (Figs. 4, 5). A circle with 8
sectors (4 classes) was overlaid over the center of each

15 neuroblastoma cell, oriented towards the nearest
oligodendrocyte cell body, and the neuroblastoma processes
counted in each sector (Fig. 5).

6.1.5.   PREPARATION OF MYELIN

20   Spinal cords were dissected from 200 g rats,
carefully cleaned from adhering dorsal and ventral roots,
and homogenized (polyton, 30 seconds at half maximal speed).
Sciatic nerves were dissected, minced and homogenized.
Myelin fractions were isolated by flotation of low speed

25 supernatants on sucrose density gradients (Colman et al.,
1982, J. Cell Biol. 95:598-608). In some experiments, to
remove possible trapped contaminants, the crude membrane
fraction was washed following hypotonic shock.
Sedimentation in hypotonic medium was achieved at 10,000 x g

30 for 5 minutes. Membrane fractions in sucrose solutions
containing no more than 50 mM ionic species were adsorbed
for several hours onto the wells of PLYS-coated tissue
culture dishes (about 0.1 mg of protein per cm^2 of tissue
culture dish). Unbound membranes were removed by three

35 washes with CMF-Hank's solution. Coated dishes were then
immediately used in substrate testing experiments. In

experiments with sympathetic or sensory neurons small
droplets of central or peripheral myelin were deposited in
defined patterns over 35 mm culture dishes.

Sympathetic or sensory neurons cultured as
5   described above were examined after 12 hours to 4 days,
neuroblastoma cells after 5-24 hours, and 3T3 cells after
1-4 hours. For quantification, neuroblastoma cells were
classified as round cells, cells with filopodia or short
processes, or cells with processes longer than one cell body
10 diameter. 3T3 cells were classified as round cells, cells
with filopodia or short processes, or large flat cells.
Three to four micrographs per culture were taken at random
from 3 cultures for each experimental point.

15   6.2.   RESULTS

6.2.1.   CULTURES OF DISSOCIATED YOUNG OR ADULT RAT OPTIC NERVES

GFAP positive astrocytes accounted for about 30%
20 of the cells in dissociated 10 day old rat optic nerves.
About 50% of the cells were positive for the O_4 antigen, a
marker for differentiated, (GalC-positive) and immature
(A_2B_5-positive) oligodendrocytes. No overlap was seen in
the labeling between O_4 and GFAP or O_4 and Thy-1, confirming
25 the specificity of the O_4 antibody as a marker for the
oligodendrocyte family (Sommer and Schachner, 1981, Dev.
Biol. 83:311-327). Thy-1-positive fibroblasts with large
flat morphologies accounted for about 20% of the cells in
young rat optic nerves.

30

6.2.2.   SUBTYPES OF OLIGODENDROCYTES

In cultures from 7-10 day old rats, about 50% of
the O_4-positive cells were A_2B_5-labeled cells. Such cells
were O_1-negative (Table I) and had different morphologies,
35 including cells with irregular processes from polygonal cell
bodies, flat cells with peripheral processes, bipolar cells,
or cells decorated with filopodia. On the basis of this

marker profile ($A_2B_5^+$, O_4^+, O_1^-) and in agreement with
Schnitzer and Schachner (1982, Cell Tissue Res. 2245:625-
636), we interpret these cells as being precursor and
immature oligodendrocytes and collectively called them

5   "immature oligodendrocytes". This cell group is probably
heterogenous, as is also suggested by the different
morphologies. Filopodia-carrying cells may be the most
advanced (Table I).

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TABLE I

A: OLIGODENDROCYTE SUBPOPULATIONS (7 DAY OPTIC NERVES, 2 DAYS IN CULTURE) DIFFER IN THEIR LABELING BY THE ANTIBODY A_2B_5

	Percentage of Labeled Cells		
	$A_2B_5^+/O_4^-$	$A_2B_5^+/O_4^+$	$A_2B_5^-/O_4^+$
Highly branched oligodendrocytes	0	9±4	91±4
Cells with irregular or polygonal shapes:			
− flat membraneous cells	37±4[a]	51±6	12±6
− process-bearing cells	18±5	74±5	8±2
− cells with filopodia	0	57±8	43±8

B: OLIGODENDROCYTE SUBPOPULATIONS (7−10 DAY OPTIC NERVES, 2 DAYS IN CULTURE) CHARACTERIZED BY THE ANTIBODIES O_1 (GalC) and A_2B_5*

	Percentage of Labeled Cells		
	$A_2B_5^+/O_1^-$	$A_2B_5^+/O_1^+$	$A_2B_5^-/O_1^+$
Highly branched oligodendrocytes	0	7±2	93±2
Cells with irregular or polygonal shapes:			
− flat membraneous cells	100	0	0
− process-bearing cells	84±6	14±6	1.5±1.5
− cells with filopodia	91	1	(8±8)[b]

* Dissociated 7−10 day old rat optic nerve cells were cultured on PORN for 2 days and labeled by either first antibody A_2B_5 (detected by anti-mouse FITC) followed by O_4 or O_1 (detected by anti-mouse-RITC) or vice versa. The proportion of double-labeled cells was calculated from the values obtained for $A_2B_5^+/O_{4/1}^-$ and $A_2B_5^+/O_{4/1}^+$ cells. Values represent the means ± SEM of 4−6 cultures (120−200 cells/culture) from 2 separate experiments.

a) This population of $A_2B_5^+/O_{4/1}^-$ cells contains type II astrocytes and precursor cells not expressing any oligodendrocyte marker.

b) Variable, weak, granular staining

About 50% of the O_4-positive cells were A_2B_5-negative and O_1-positive after 2 days in culture under our culture conditions. Most of these cells showed a typical, highly branched radial process network. Due to this characteristic morphology we called these cells highly branched oligodendrocytes (Table I). After 2 days in culture, most highly branched oligodendrocytes from optice neres of 10 day old rats were stained with an antiserum against myelin basic protein (MBP). We therefore interprete these cells as being myelin forming oligodendrocytes. Their characteristic process network may be the result of an unstable, partially collapsed myelin membrane containing occasional flat membrane areas. The total yield of cells from adult nerves was very low. Both, differentiated O_1-positive highly branched oligodendrocytes as well as immature A_2B_5-positive oligodendrocytes were also present in cultures of adult tissue.

6.2.3. RESPONSE OF VARIOUS CELL TYPES TO
HIGHLY BRANCHED OLIGODENDROCYTES

6.2.3.1. CO-CULTURES WITH SYMPATHETIC
OR SENSORY NEURONS

5   Dissociated cells from newborn rat superior
cervical ganglia or dorsal root ganglia were added to glial
cells after 2 - 10 days in culture. Ganglionic Schwann
cells and fibroblasts were eliminated by pulses of Ara C in
some of the experiments. NGF (50 or 100 ng/ml) was added to
10   the culture medium, leading to a rapid fiber outgrowth and
to the formation of dense neurite networks within a few
days. NGF alone had no effect on the occurrence and
morphology of oligodendrocytes. Glial cell types were
identified by antibody staining at the end of the
15   experiments (2 days to 2 weeks of co-culture).

In cultures with a dense neurite plexus, the most
striking observation was the occurrence of "windows" free of
neurites in the center of which cells with radial, highly
branched processes could be observed (Fig. 1). Antibody
20   staining identified these cells as highly branched
oligodendrocytes. A quantification of the interaction of
oligodendrocytes with sympathetic ganglion cells is shown in
Figures 2a and 2b. Astrocytes adjacent to oligodendrocytes
were rare in these cultures since the overall glial cell
25   density was low; preferential association with astrocytes
could, therefore, not account for this result. Highly
branched oligodendrocytes excluded neurons from their
territory irrespective of the culture substrate used. The
same "windows" were formed on plain plastic, collagen, PORN-
30   or laminin-coated culture dishes. No difference was seen
between sympathetic and sensory neurons; both were excluded
from the territory of highly branched oligodendrocytes.
Likewise, Schwann cells, when present, did not invade or
overgrow the oligodendrocyte process networks (Fig. 1b). In
35   contrast, immature oligodendrocytes, characterized by their
irregular shapes and the absence of O_1-antigen, did allow

reurite growth on their processes and cell bodies (Figs. 1b,
1e, 1f). A_2B_5 could not be used as a marker for immature
oligodendrocytes in co-cultures with neurons, as this
antigen was rapidly lost after addition of the neurons.

5   Recent direct observations of the encounter of growth cones
with oligodendrocytes showed that growth cone movement was
arrested after filopodial contact is established. Normal
growth cone activity was seen during contact and crossing of
·immature cells. These observations also exclude the

10   possibility that the "windows" were formed secondarily in
the neurite plexus. Astrocytes in the same cultures were
often overgrown by single neurites or neurite bundles (Figs.
3a, 3b). This was true for both morphological types, flat
·and stellate cells.

15

6.2.3.2. CO-CULTURES WITH FETAL RAT RETINAL CELLS
         After plating retinal cells at monolayer density
on top of 5 day old cultures of optic nerve non-neuronal.
cells, a typical rearrangement of the retinal cells could be

20. observed; whereas oligodendrocyte precursor cells were often
contacted by retina cells, the highly branched
oligodendrocytes were mostly free of them (Figs. 1g, 1h, 3c,
3d). Again, astrocytes were preferred as a substrate over
PORN.

25

6.2.3.3. RESPONSE OF OTHER CELL TYPES TO
HIGHLY BRANCHED OLIGODENDROCYTES
         Neuroblastoma cells (line NB-2A) were plated at
high cell density into dissociated optic nerve cultures and
.stimulated for fiber production by 2 mM dibutyryl-cyclic-AMP

30   or by GdNPF. Seven, 24 or 48 hours later, the cultures were
fixed and oligodendrocytes were identified by antibodies O_4
and O_1. Again, the territories of highly branched
oligodendrocytes were clearly spared by neuroblastoma cells
(Figs. 4a, 4b). Processes produced by neuroblastoma cells

35   situated close to oligodendrocytes were pointing away from
the oligodendrocytes (Figs. 4a, 4b; Fig. 5 and Table IA).

TABLE IA

ORIENTATION OF NEUROBLASTOMA PROCESSES
WITH REGARD TO HIGHLY BRANCHED OLIGODENDROCYTES

Sector[†]	% of Processes in Each Sector	
	Adjacent Neuro-blastoma Cells	Distant Neuro-blastoma Cells
1	7 ± 1.4	25 ± 2.4 ***
2	34 ± 1.2	26 ± 1.2 ***
3	33 ± 2.7	25 ± 2.3 *
4	26 ± 2.3	24 ± 2.7

[†] Shown in Figure 5

* $p < 0.0.05$

*** $p < 0.001$

Primary culture <u>fibroblasts</u> and astrocytes in the optic nerve preparations as well as mouse <u>3T3 cells</u> showed a drastic "avoidance behavior" towards highly branched oligodendrocytes. 3T3 cells plated at high cell density into optic nerve glial cultures attached and flattened out between 30 minutes and 3 hours on the PORN substrate. In these forming monolayers, characteristic "windows" appeared corresponding to the territories of highly branched oligodendrocytes (Figs. 4c, 4d). At the sites of contact, 3T3 cells formed a crescent-shaped bulge of cytoplasm. Lamellipodia were absent in this region. Significantly, fibroblasts that landed directly on highly branched

oligodendrocytes completely failed to spread. As for
neurons, immature oligodendrocytes were not visibly avoided
by 3T3 cells (Fig. 6).

5   6.2.4. ABSENCE OF SPECIES SPECIFICITY
           Neither the specific morphology nor the
unfavorable substrate property of oligodendrocytes were
species specific. Dissociated non-neuronal cells from E13
and E17 chick optic nerve contained besides O_4-
10 positive/A_2B_5-negative/O_1-positive highly branched
oligodendrocytes. 3T3 cells plated on top of chicken non-
neuronal cells formed the characteristic "windows" around
these chick oligodendrocytes.

15   6.2.5.   MYELIN AS A SUBSTRATE
           The properties of myelin as a substrate for
neurons or fibroblasts were also tested, since myelin
consists of spirally wrapped oligodendrocyte membranes.
Crude myelin fractions from adult rat spinal cord or sciatic
20 nerve were prepared by flotation on a sucrose gradient. The
myelin was adsorbed to PLYS-coated tissue culture dishes and
tested for its substrate properties for superior cervical
ganglion cells, dorsal root ganglion cells, neuroblastoma
cells and 3T3 cells. All four cell types attached poorly to
25 CNS myelin and showed marked difficulties in their process
outgrowth. Sympathetic and sensory neurons on CNS myelin
remained round or produced short, abortive fibers in spite
of the presence of NGF (50 ng/ml or 100 ng/ml) (Figs. 7a,
17c). In contrast, long fibers were produced on islets of
30 sciatic nerve myelin in the same culture dishes (Figs. 7b,
17d). Small CNS myelin islets on PLYS appeared as "windows"
outlined by excluded neurites, whereas PNS myelin-PLYS
boundaries were apparently not detected by growing neurites.
           Process outgrowth from neuroblastoma cells (line
35 NB-2A) in the presence of dibutyryl-cyclic AMP was
significantly reduced by CNS myelin (Fig. 8A).

Spreading of 3T3 fibroblasts was strongly
inhibited by CNS myelin (Fig. 8B). 3T3 cells remained round
or produced spindle-shaped or polygonal morphologies with a
minimal cell substrate interaction. In contrast, large flat

5   membranes were produced within 20 - 30 minutes on polylysine
and, with a somewhat slower time-course, also on myelin from
the peripheral nervous system (Fig. 8B). Nonpermissiveness
was associated, at least in large part, with myelin
membranes, since sedimentation at 10,000 x g for 5 minutes

10 under hypotonic conditions (see Section 6.1.5., supra) was
sufficient to pellet most nonpermissive membranes. Under
these conditions, most surface membrane components floating
to densities smaller than the one of 0.85 M sucrose, would
not be expected to sediment.

15   CNS myelin nonpermissiveness is not due to
astrocyte membranes, since a cell membrane preparation from
CNS tissue containing minimal amounts of white matter
(superficial cortical layers) was a permissive substrate for
fibroblast spreading.

20   These experiments show that, in parallel to the
effects of living, highly branched oligodendrocytes, myelin
from the CNS is also a strongly nonpermissive substrate for
primary culture neurons, neuroblastoma cells, and 3T3
fibroblasts. Myelin from the peripheral nervous system does

25 not show a comparable nonpermissive substrate effect.

6.3.   DISCUSSION

            In the present study, we observed that myelin
forming oligodendrocytes and isolated CNS myelin exert a

30 nonpermissive substrate effect on outgrowing neurites of
sympathetic and sensory neurons and neuroblastoma cells, as
well as for the attachment of retinal cells and the
spreading of fibroblasts.

            Several classes of cells were present in short-

35 term cultures of dissociated rat optic nerves:
oligodendrocytes, astrocytes (GFAP-positive) fibroblasts

(Thy-1, fibronectin-positive) and several types of precursor cells. Within the oligodendrocyte family (O_4-positive; Sommer and Schachner, 1981, Dev. Biol. 83:311-327), one main subtype of cells was characterized by the absence of the O_1

5 antigen (GalC) and of MBP, two components highly characteristic of myelin (Mirsky, et al., 1980, J. Cell Biol. 84:483-494), and the presence of binding sites for the antibody A_2B_5. A_2B_5 was shown to be a marker for oligodendrocyte/type II astrocyte precursors, type II

10 astrocytes, and neurons (Schnitzer and Schachner, 1982, Cell Tissue Res. 224:625-636; Abney, E.R. et al., 1981, Dev. Biol. 100:166-171; Raff, et al., 1983, Nature 303:390-396). Therefore, we considered this cell class to represent immature oligodendrocytes, probably including precursors

15 such as those described by Dubois-Dalcq (1986, Soc. Neurosci. Abstr. 12:767) and Sommer and Noble (1986, Soc. Neurosci. Abstr. 12:1585). The presence of O_4 distinguishes these cells from the O2A precursors (Raff, M.C. et al., 1983, Nature 303:390-396). These immature cells showed

20 irregular and variable morphologies with bipolar shapes or polygonal cell bodies and irregular processes, often decorated with filopodia. The cell class is probably heterogenous; cell division could be observed. The second main oligodendrocyte subclass consisted of A_2B_5-negative,

25 O_1-positive cells, possessing a radial, highly branched and anastomosing process network. Most of these highly branched oligodendrocytes in 2 day old cultures of 10 day old rat optic nerves were positive for MBP under our culture conditions. We thus interpret this frequent cell type as

30 representing oligodendrocytes actively involved in the synthesis of myelin membranes which are deposited flat on the culture substrate in the absence of axons. These membranes are unstable and collapse to form the characteristic, anastomosing process network. This cell

35 type has been described as "hairy eyeball cell" (Sommer and Schachner, 1981, Dev. Biol. 83: 311-327), and formation of

whorls of compact myelin by such cells has been observed
after prolonged times in culture (Rome et al., 1986, J.
Neurosci. Res. 15:49-65; Yim et al., 1986, J. Biol. Chem.
261:11808-11815).

5   Both immature and myelin forming oligodendrocytes
were seen in cultures of 7 to 10 day old or adult rat optic
nerves, and also in cultures of 1 day rat optic nerves,
newborn rat spinal cord or adult rat corpus callosum, as
well as in cultures of spinal cord and optic nerves of E13

10   or E17 chicken embryos. Immature cells clearly were
predominant in dissociates from younger stages, but the
large drop in cell yield upon dissociation with increasing
age precluded any quantitative population analysis.
However, immature oligodendrocytes could also be obtained

15   consistently from adult rat white matter tissues, confirming
earlier observations by French-Constant and Raff (1986,
Nature 319:499-502).

        The addition of neurons to established glial
cultures showed dramatic differences in substrate properties

20   for neuronal attachment and fiber outgrowth among the
various types of non-neuronal cells. Astrocytes,
particularly the flat reactive protoplasmic astrocytes, were
adhesive and favorable for neuronal attachment and
outgrowth, in agreement with earlier observations (Foucaud

25   et al., 1982, Cell Res. 137:285-294; Hatten, et al., 1984,
J. Cell Biol. 98:193-204; Noble, et al., 1984, J. Neurosci.
4:1982-1903; Fallon, 1985, J. Cell Biol. 100:198-207).
Immature oligodendrocytes also were frequently contacted by
neurites or nerve cell bodies. This behavior could be of

30   high physiological relevance. During development,
oligodendrocyte precursors migrate into the already formed
axonal bundles and extend processes to contact a certain
number of axons. These processes then start to enwrap and
spiral around the axons, thus forming the structure called

35   myelin (Wood and Bunge, 1984, W. T. Norton, ed., 1-46).

In sharp contrast to astrocytes and oligodendrocyte precursors, we found that myelin forming oligodendrocytes display strongly nonpermissive substrate properties for neuronal attachment and fiber outgrowth as well as for

5   fibroblast attachment and spreading. This effect was strong and pronounced even on laminin-coated culture dishes, which otherwise represent an excellent substrate for neurite growth (Manthorpe, et al., 1983, J. Cell Biol. 97:1882-1980; Rogers, et al., 1983, Dev. Biol. 98:212-220). This effect

10   was not overcome by high doses of NGF in cultures of sympathetic and sensory neurons, or GdNPF or dibutyryl-cyclic-AMP in cultures of neuroblastoma cells. A similar or identical nonpermissive substrate property was associated with rat CNS myelin but not with myelin from peripheral

15   nerves. The effect was strictly contact-dependent, since nerve cells or fibroblasts grew well and were free to move in the immediate surrounding of these oligodendrocytes or of CNS myelin islets. Mouse 3T3 cells were also inhibited by chicken oligodendrocytes, showing that this effect is not

20   species-specific.

In the rat optic nerve, the peak number of axons is reached at embryonic day 20, followed by a dramatic loss of axons (Crespo, et al., 1985, Dev. Brain Res. 19:129-134). Oligodendrocyte precursors appear from E17 onward (Raff, et

25   al., 1985, Cell 42:61-69) and express GalC around birth (Miller, et al., 1985, Dev. Biol. 111:35-41). The first myelin detectable by electron microscopy appears at postnatal day 6 (Hildebrand and Waxman, 1984, J. Comp. Neurol. 224:25-37). This clear-cut temporal dissociation

30   between axonal growth and myelin formation is also present in chicken optic nerves (Rager, 1980, Cell Biol. 63:1-92) and, although less well studied, in many white matter tracts of the CNS (Matthews and Duncan, 1971, J. Comp. Neurol. 142:1-22; Looney and Elberger, 1986, J. Comp. Neurol.

35   248:336-347). During normal development, growing axons therefore probably never encounter myelin or myelinating

oligodendrocytes within their fascicles, but rather interact
with precursors and immature oligodendrocytes. The
extremely slow time-course observed for in vitro myelination
(Wood, et al., 1980, Brain Res. 196:247-252; Wood and
5 Williams, 1984, Dev. Brain Res. 12:225-241) could be
consistent with a situation where undifferentiated
oligodendrocytes first interact with axons and are then
induced to differentiate and to form myelin.

In contrast to development, during CNS
10 regeneration, axonal growth cones or sprouts do encounter
mature oligodendrocytes and myelin. Substrate properties of
CNS tissue, in particular the absence of potent neurite
promoting substrates like laminin in the differentiated CNS
of higher vertebrates, are important aspects in the context
15 of CNS regeneration (Liesi, 1985, EMBO J. 4:2505-2511;
Carbonetto, et al., 1987, J. Neurosci. 7:610-620). However,
since myelin and oligodendrocytes persist for a long time in
denervated CNS tracts (Fulcrand and Privat, 1977, J. Comp.
Neur. 176:189-224; Bignami, et al., 1981, J. Neuropath, Exp.
20 Neurol. 40:537-550), the absence of any fiber regeneration
in white matter areas in contrast to peripheral nerves and
PNS/CNS transplants could be related to these nonpermissive
substrate factors.

Under normal conditions, blocking certain
25 territories for later growing axonal populations during
development, antagonism between favorable and nonpermissive
substrate molecules during development of CNS projection
patterns, or the spatial limitation of sprouting in the
differentiated CNS are possible functions for this
30 oligodendrocyte associated nonpermissive substrate property.

35

7. INVOLVEMENT OF A METALLOPROTEASE IN GLIOBLASTOMA INFILTRATION INTO CENTRAL NERVOUS SYSTEM TISSUE IN VITRO

In the examples detailed herein, we describe a membrane-associated metalloprotease which plays a crucial

5 role in the malignant tumor infiltration of CNS tissue _in vitro_ by the rat glioblastoma cell line C6.

We have discovered that malignant tumor infiltration of CNS tissue _in vitro_ by the glioblastoma line C6, requires a plasma membrane bound metallodependent

10 degradative activity. C6 cells infiltrate optic nerve explants, attach and spread on white and grey matter of cerebellar frozen sections or on CNS myelin. The metal ions chelator 1,10-phenanthroline and the dipeptide cbz-tyr-tyr, but not inhibitors for three other classes of proteases,

15 blocked up to 67% of C6 cell spreading on CNS myelin. A metallodependent activity neutralizing CNS myelin inhibitory substrate properties toward 3T3 cells, is associated with a C6 plasma membrane fraction. The same inhibitors of metalloprotease also impaired infiltration of CNS nerve

20 explants and spreading on the CNS white matter of cerebellar frozen sections.

7.1. MATERIALS AND METHODS
7.1.1. CELL CULTURES

25 Rat C6, mouse NIH 3T3 and B16 cells were cultured in Dulbecco's modified Eagle's medium (DMEM) supplemented with 10% fetal calf serum (FCS), usually to maximally 70-80% confluency. Cells were harvested with a short trypsin treatment (0.1% in Ca^{2+}/Mg^{2+}-free Hank's medium for 90

30 seconds) stopped by addition of FCS in excess, collected by centrifugation. Cells were resuspended in either DMEM/FCS or defined serum-free medium (MEM) and used for experiments. Dissociated rat CNS glial cells were prepared starting from optic nerves of 6-7 days old Lewis rats as described in

35 Section 6.1.1, _supra_ and plated into poly-D-lysine (PLYS) coated wells (100 mm^2, 100 μl medium) at a density of 20,000

cells per well. The culture medium was an enriched L15 medium with 5% rat serum, penicillin and streptomycin. C6, 3T3 and B16 cells were added to 2 day old cultures at a concentration of 30,000 cells per well, incubated for two

5   hours and fixed with warm 4% formalin in phosphate buffer. Inhibitory oligodendrocytes were identified by double labelling using the specific antibodies O_1 and O_4 (see Section 6.1.3, *supra*).

10   ### 7.1.2.   PREPARATION OF NERVE EXPLANTS FOR INFILTRATION ASSAY

Optic nerve and sciatic nerve explants were prepared as described (Schwab and Thoenen, 1985, J. Neurosci. 5:2415-2423). Briefly, the nerves were rapidly

15   dissected from about 8 week old male rats, cleaned from the meninges, 3 times frozen and thawed using liquid nitrogen, and placed under a teflon ring (diameter 13 mm, thickness 1 mm) sealed to a culture dish with silicon grease. Two chambers connected only by the explants were in this way

20   obtained. 300,000 C6, 3T3 or B16 cells were plated in the inner chamber in DMEM/FCS and incubated for 5 to 20 days. The medium was changed every other day. Cultures were fixed overnight with 4% formalin. The nerve explants were mounted with Tissue-Tek, 10 to 15 μm sections were cut in a

25   cryostate and collected on gelatine coated cover slips. After drying at room temperature overnight, the sections were stained in 0.75% cresyl violet, and evaluated. The infiltrated cells were counted for each 0.1 mm of the explants, starting from the tip where cells were added. Due

30   to the 15 day incubation, the explants were often different in diameter. Therefore, only the central part of the nerves (0.25 mm) were considered, since only this part of the explants presented a good histological quality. Inhibition experiments were performed with nerve explants previously

35   injected from both sides with 2 μl of 3 mM cbz-tyr-tyr or cbz-ala-phe solutions.

7.1.3. CNS FROZEN SECTIONS AND MYELIN AS SUBSTRATES

Adult rat cerebellum frozen sections were prepared and dried on glass coverslips. 70,000 C6, 3T3, or B16 cells in 100 μl were added to each well containing

5 slices previously rinsed with cold DMEM/FCS. Cultures were incubated for 2 days at 37°C. Cultures were then fixed and stained with cresyl violet. Three to four cerebellum slices were used per point per experiment, with each experiment being repeated at least 2 times.

10   Myelin from rat spinal cord (CNS) or sciatic nerve (PNS) purified on a discontinuous sucrose gradient as described in Section 6.1.5., was dried overnight onto PLYS coated wells (20 μg protein/well of 100 mm^2 surface). Unbound membranes were removed by three washes with

15 Ca^{2+}/Mg^{2+}-free Hank's solution. Myelin coated wells were immediately used in substrate testing assays by the addition of 9,000 cells (C6, 3T3, or B16) per cm^2. Alternatively, we used extracted CNS myelin protein, or SDS-PAGE purified 35 and 250 kD inhibitory proteins reconstituted in liposomes

20 (see Caroni and Schwab, 1988, J. Cell Biol. 106:1281-1288). Experiments were scored at different time points using a phase contrast microscope equipped with a photocamera. Quantifications were done using a surface integration program; three arbitrary fields were photographed for each

25 well at a magnitude of 80X, at least 25 cells per picture were measured. Each point represents the mean of at least 3 wells ± SEM. Results are expressed as μ^2 of projected cell surface, or as degree, which was calculated by subtracting from the projected surface value of a spreading cell, the

30 surface value of a completely spheric cell.

7.1.4. C6 PLASMA MEMBRANES AND CONDITIONED MEDIUM PREPARATION

C6 cells grown to 80% confluency were washed

35 twice with Hank's medium, and harvested in 20 ml 8.5% sucrose, 50 mM NaCl, 10 mM Tris buffer, pH 7.4, using a rubber policeman. After mechanical homogenization through a

series of needles of decreasing size, a low purity plasma membrane fraction was obtained by centrifugation (5 minutes at 3000 x g, 10 minutes at 8000 x g, and then 2 hours at 100,000 x g). A higher purity fraction was isolated by

5   loading the material on a discontinuous sucrose gradient, containing 50 mM NaCl, 10 mM Tris, pH 7.4 (Quigley, 1976, J. Cell Biol. 71: 472-486). 20-40% sucrose interphase (C6 plasma membranes fraction) and 40-60% sucrose interphase (C6 mitochondrial fraction) were collected, washed in Hank's

10   medium and resuspended in MEM.

Conditioned media were obtained by cultivating 80% confluent C6 cell cultures for 1 day in MEM. The medium was then collected and centrifuged for 10 minutes at 3000 x g. In some experiments the conditioned medium was

15   concentrated 10 times using Centricon Tubes.

7.1.5.   TREATMENT OF CNS MYELIN WITH C6 PLASMA MEMBRANES

CNS myelin coated PLYS wells were prepared as described in the previous section, but instead of being

20   immediately tested as substrate, they were first incubated with 50 μl of C6 plasma membranes (containing 0.8 mg protein/ml MEM) at 37° for 30 minutes. Dishes were then rinsed twice with Hank's medium and immediately used as substrates for 3T3 cells. In some experiments, protease

25   blockers were added to the membranes using 10 times concentrated solutions.

7.2.   RESULTS

7.2.1.   C6 GLIOBASTOMAS BUT NOT 3T3 FIBROBLASTS
30   OR B16 MELANOMAS INFILTRATE OPTIC NERVE
              AND CNS WHITE MATTER IN VITRO

Frozen optic nerve and sciatic nerve explants were placed under a teflon ring and sealed with silicon grease (Schwab and Thoenen, 1985, J. Neurosci. 5:2415-2423). C6 or 3T3 cells were plated into the ring, in contact with

35   one end of the nerve explants. Culture medium was exchanged every other day, and after 5 to 20 days of incubation the

nerves were fixed, and sectioned with a cryotome.
Infiltrated cells were recognized by cresyl violet staining.
PNS explants supported diffuse infiltration of both C6 and
3T3 cells (Figs. 9c, d). C6 cells were present in the

5   explants at higher density. In the optic nerve explants, a
different picture emerged (Figs. 9a, b); 3T3 cells did not
infiltrate the nerves, with the exception of very few cells
which migrated along blood vessels (Fig. 9b, arrow). On the
other hand, C6 cells infiltrated deep into the optic nerves

10   with a diffuse pattern, reaching a maximum distance of about
3 mm from the entry point in 14 days (migration rate: about
0.2 mm/day).

As an alternative model, adult rat cerebellum
frozen sections were used as a culture substrate for C6, B16

15   or 3T3 cells. The highly metastatic B16 melanoma cells were
found to clearly discriminate between the substrate
qualities of the grey and white matter with regard to cell
attachment, spreading and migration. In fact, B16 cells
exclusively attached and spread on grey matter regions and,

20   even if plated at high cell densities, they did not attach
on or migrate into white matter areas of the sections (Fig.
10e). The same picture emerged for 3T3 cells, which formed
dense monolayers on grey matter, but not on white matter
(Figs. 10c, d). In contrast to B16 and 3T3 cells, C6 cells

25   were found frequently on white matter as well as on grey
matter (Fig. 10a, b). In some cases we found that C6 cells
were more dense on the white matter than on the molecular
layer of the grey matter, where they often formed little
aggregates which spread with difficulty.

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7.2.2.   GLIOBLASTOMA CELL SPREADING
IS NOT INHIBITED BY CNS MYELIN

The spreading behavior of C6 glioblastomas on CNS
myelin adsorbed to PLYS coated wells was compared to that of

35   B16 melanomas and 3T3 fibroblasts. B16 melanoma reaction to
a CNS myelin substrate strongly resembled that of 3T3
fibroblasts: 3T3 or B16 cells spreading on CNS myelin was

strongly impaired, whereas C6 cell spreading was slightly
reduced at the beginning (90 minutes), but no further
appreciable differences were detected at later time points
(Fig. 11). The differences between cells on CNS myelin or
5 on PLYS also persisted with prolonged incubation times (up
to 1 day).

C6 cells were confronted with the SDS-PAGE
purified inhibitors (35 kD and 250 kD) reconstituted in
liposomes, and also with living, cultured oligodendrocytes.
10 Again, 35 kD and 250 kD liposomes strongly inhibited 3T3
cell spreading, but they did not impair C6 cell spreading;
C6 cells adhered and rapidly assumed the well spread
characteristic "fried egg" appearance also on these
reconstituted CNS myelin fractions.
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7.2.3.   SPECIFIC BLOCKERS OF METALLOPROTEASES INHIBIT
          C6 CELL SPREADING ON CNS MYELIN

The involvement of proteases in C6 behavior was
investigated by determining the effect of inhibitors of
proteases on C6 cell spreading on either CNS myelin or PLYS.
20 Cys-, Ser- and Asp-protease blockers at the adequate
concentrations had no discernible effect on C6 spreading on
CNS myelin (Table II).

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TABLE II

EFFECT OF DIFFERENT PROTEASE INHIBITORS ON C6 CELL SPREADING ON PLYS OR CNS MYELIN*

Protease Class	Protease Inhibitor		Spreading on: PLYS / CNS (% of control on PLYS)		Inhibition on CNS (%)
			PLYS	CNS	
none, control			100	95	5
serine	6-amino-capronate	3.0 mM	93	100	0
	hirudine	1.0 nM	nq	nq	0
	PMSF	4.0 mM	100	94	6
	trasylol	200.0 U/ml	98	93	5
cysteine	leupeptine	0.3 mM	91	83	8
aspartic	pepstatine	0.3 mM	98	95	3
metallo	1,10-phenanthroline	0.3 mM	97	30	67
	bestatine	0.1 mM	nq	104	0
	phosphoramidon	0.3 mM	nq	91	9
	TIMP	10.0 !g/ml	102	93	9
	cm-phe-leu	0.5 mM	95	92	3
	cbz-gly-gly-NH$_2$	1.0 mM	nq	99	1
	cbz-gly-phe-NH$_2$	1.0 mM	100	45	55
	cbz-ala-phe	0.3 mM	98	90	8
	cbz-tyr-tyr	0.3 mM	101	56	45
general	2-macroglobulin	3.0 !M	70	52	18
	cocktail -		nq	nq	0
	cocktail +		nq	nq	++

*Cells were plated on PLYS or CNS myelin coated culture dishes. Spreading was determined after 150 minutes as described supra in Materials and Methods. Inhibition values were calculated by subtracting spreading values on CNS myelin from the values on PLYS.

PMSF: Phenyl methyl sulfonyl fluoride.
TIMP: Tissue inhibitor of metalloproteases.
Cocktail -: trasylol, 200 U/ml; leuptine, 0.3 mM;
           pepstatine, 0.3 mM.
Cocktail +: same as cocktail -, but with 0.3 mM 1,10-phenantroline.
nq: not quantified, only qualitative

The specific metalloprotease blocker 1,10-phenanthroline on the other hand, resulted in a strong inhibition of C6 spreading specifically on CNS myelin: 1,10-phenanthroline inhibited C6 spreading on myelin up to 67% after 2 hours in

5   culture (Table II). None of the blockers tested showed a significant effect on C6 cell spreading on PLYS. 1,10-phenanthroline is a general metalloprotease inhibitor due to its property of metal ion chelation. However, inhibition by this substance is not sufficient to define a proteolytic

10   activity, since other metallodependent enzymes are also inhibited. Many other inhibitors of metalloproteases have been found, but they usually turned out not to be as general as 1,10-phenanthroline. Phosphoramidon (Komiyama, et al., 1975, Biochem. Biophys. Res. Comm. 65:352-357), bestatine

15   (Umezawa, et al., 1976, J. Antibiot. 29:857-859) and the tissue inhibitor of metalloprotease (TIMP; Cawston, et al., 1987, Biochem. J. 195:159-165) did not impair C6 cell spreading (Table II).

         TIMP also does not inhibit a brain membrane

20   associated metalloprotease degrading enkephaline. Carboxymethyl-phe-leu (Fournie-Zaluski, M.C. et al., 1983, J. Med. Chem. 26:60-65), a modified peptide with high affinity for enkephalinase (Almenoff, J. and M. Orlowski, 1983, Biochemistry 22:590-599), did not inhibit C6 cell spreading

25   (Table II). On the other hand, we found that the dipeptides cbz-gly-phe-NH_2 and cbz-tyr-tyr lead to 55% inhibition of C6 cell spreading on CNS myelin, but not on PLYS, PNS myelin or glass. These peptides are substrate peptides with metalloprotease specificity (Almenoff and Orlowski, supra;

30   Baxter, et al., 1983, Proc. Natl. Acad. Sci. U.S.A. 80:4174-4178; Couch and Strittmatter, 1983, Cell 32:257-265; Chen and Chen, 1987, Cell 48:193-203; Lelkes and Pollard, 1987, J. Biol. Chem. 262:15496-14505).

         In order to exclude a possible general enhancement

35   of C6 cell spreading on nonpermissive substrates, we tested metalloprotease-dependent C6 cell spreading on two other

substrates in addition to PLYS and CNS myelin (Fig. 12): PNS
myelin and glass. PNS myelin was chosen as a control for the
general properties of a myelin membrane fraction (e.g., high
content of lipids), and glass was chosen because of its well

5   known bad substrate qualities. Half maximal inhibition of
spreading on CNS myelin was obtained with 200 μM 1,10-
phenanthroline. On PLYS, glass, and PNS myelin (Fig. 12),
1,10-phenanthroline did not impair C6 cell spreading at
concentrations up to 0.5 mM (Fig. 12).

10   Absorption of CNS myelin with a monoclonal
antibody (IN-1) raised against CNS myelin inhibitory
components (see Caroni and Schwab, 1988, Neuron 1:85-96)
largely reversed 1,10-phenanthroline dependent inhibition of
C6 cell spreading on CNS myelin liposomes (Table III). IN-1

15   also almost completely neutralized the inhibitory substrate
property of CNS myelin protein liposomes for 3T3 cells
(Table III).

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TABLE III

INHIBITION OF C6 CELL SPREADING BY
1,10-PHENANTHROLINE ON CNS MYELIN
IS NEUTRALIZED BY ANTIBODY IN-1*

Cells	Antibody	1,10-Phenan-throline	Spreading value on: CNS lipos.	PLYS	% inhibition on CNS lipos.
3T3	–	0	1.11	2.00	45
3T3	IN-1	0	2.03	2.26	10
3T3	mouse IgM	0	1.16	2.18	47
C6	–	0	2.48	2.52	2
C6	–	0.3 mM	1.35	2.49	46
C6	IN-1	0	2.46	2.48	1
C6	IN-1	0.3 mM	2.25	2.54	11
C6	mouse IgM	0	2.36	2.42	2
C6	mouse IgM	0.3 mM	1.41	2.39	41

*CNS myelin protein liposomes were used as substrates, and
were preadsorbed with monoclonal antibody IN-1 against the
myelin inhibitory substrate constituents (see Caroni and
Schwab, 1988, Neuron 1:85-96), or with mouse IgM. Spreading
was calculated after 150 minutes and is expressed as $!m^2$
10^3. % Inhibition relates to spreading values on PLYS.

These results indicate that the metalloprotease(s) plays an

important role for overcoming of CNS myelin inhibitory

substrates by neutralization of IN-1 inhibitory properties.

7.2.4. A C6 PLASMA MEMBRANE ASSOCIATED ACTIVITY NEUTRALIZES THE INHIBITORY SUBSTRATE PROPERTY OF CNS MYELIN

CNS myelin-coated culture wells were incubated

with C6 conditioned medium or C6 plasma membranes, and

subsequently tested for their inhibitory substrate property

with spreading of 3T3 cells. We found that C6 plasma

membranes contained an activity which strongly reduced CNS

myelin inhibitory activity (Fig. 13, Table IV). The same

treatment also decreased the inhibitory effect of CNS myelin

protein liposomes or SDS-PAGE-purified, reconstituted 35 kD

and 250 kD inhibitory components. The decrease in CNS

myelin inhibitory activity for 3T3 cell adhesion and
spreading was quantitified by measuring spreading values and
DNA synthesis (Table IV).

TABLE IV

C6 PLASMA MEMBRANES REDUCE CNS MYELIN
INHIBITORY SUBSTRATE PROPERTY FOR 3T3 CELLS*

Substrates	3T3 Cell Spreading (%)	^{3}H-Thymidine Incorporation (%)
PLYS	100	100
CNS myelin	15	30
CNS myelin, C6 PM	52	83
CNS myelin, C6 PM, phen. treated	17	50
CNS myelin, C6 PM, EDTA treated	13	nd

*3T3 cells were plated on PLYS or CNS myelin. Spreading was
assessed after 150 minutes CNS myelin was preincubated with
a C6 cell plasma membrane fraction (C6 PM) in the absence or
presence of metalloprotease inhibitors as indicated. ^{3}H-
thymidine was added when 3T3 cells were plated, and
incorporation was determined after 20 hours.
nd: not determined.

1,10-phenanthroline, EDTA, and the dipeptide cbz-gly-phe-NH$_2$
completely blocked the C6 plasma membrane effect. Trasylol,
leupeptine and pepstatine did not inhibit this effect. C6
conditioned medium used as such, or 10-times concentrated,
did not contain any degradative activity able to neturalize
CNS myelin inhibitory substrate properties.

7.2.5. INHIBITORS OF METALLOPROTEASES IMPAIR C6 CELL SPREADING ON CNS WHITE MATTER AND C6 INFILTRATION OF CNS EXPLANTS

In order to investigate the relevance of the C6
plasma membrane metalloprotease activity not only for C6
cell attachment and spreading, but also for C6 cell

migration and infiltration, C6 cells were plated on cerebellar frozen sections or added to optic nerve explants in the presence of two metalloprotease inhibitors (1,10-phenanthroline and cbz-tyr-tyr). Parallel cultures

5 contained inhibitors for the three other classes of proteases (leupeptine, pepstatine or trasylol), or a control dipeptide (cbz-ala-phe).

The presence of 1,10-phenanthroline at different concentrations (50, 100, 200 and 300 μM), or the dipeptide

10 cbz-tyr-tyr (100 μM) dramatically changed the distribution and behavior of C6 cells on the white matter areas when cerebellar frozen sections were used as culture substrates (Fig. 14). C6 cells also adhered in large numbers and spread extensively on the grey matter (Fig. 14).

15   Rat optic nerves were injected with 4 μl of 3 mM solutions of either cbz-ala-phe or cbz-tyr-tyr. Cells were incubated with medium containing 0.5 mM peptide. In the outer chamber, where no cells were present, the peptide concentration was 1 mM. After 14 days, the immigration of

20 C6 cells into the explants differed greatly (Fig. 15). Cbz-ala-phe-injected nerves contained more cells, and C6 cell infiltration was not affected, as compared to explants injected with culture medium only. On the other hand, cbz-tyr-tyr inhibited C6 cell infiltration in all the 8 nerves

25 examined (2 experiments). C6 cells were found mainly at the cut end of these nerve explants, and deep infiltration, which occurred massively in control explants, was strongly reduced by cbz-tyr-tyr.

30   7.3.   DISCUSSION

The present results demonstrate that C6 glioblastoma cells, in contrast to neurons, fibroblasts and B16 melanoma cells, were not impaired in their migration into optic nerve explants or in attachment and spreading on

35 CNS white matter, isolated CNS myelin, or living oligodendrocytes. The fact that the behavior of C6 cells

differed characteristically from that of several cell types
in all the assay systems studied suggests common underlying
cell biological mechanisms, both for C6 spreading on an
inhibitory substrate as well as for C6 mobility in an

5 environment (optic nerve) which does not allow fibroblasts,
Schwann cell or melanoma cell migration nor does it allow
ingrowth of regenerating nerve fibers. This behavior of C6
cells was not due to "insensitivity" to the inhibitory
components, since C6 cell motility was drastically inhibited

10 on CNS myelin or white matter in the presence of specific
protease blockers, and this effect was reversed by selective
neutralization of myelin-associated inhibitory proteins with
a monoclonal antibody (IN-1).

          Inactivation of myelin-associated inhibitory

15 constituents occurred by living C6 cells as well as by C6
plasma membranes. Our experiments with a number of protease
blockers with different known specificities showed that this
C6 associated activity belongs to the metalloenzyme family.
The close parallelism observed between prevention of C6 cell

20 spreading on CNS myelin and prevention of inactivation of
myelin-associated inhibitory proteins strongly suggests that
modification of the inhibitory substrate components by a
metalloprotease could be the mechanism which enables C6
cells to spread on myelin, on white matter, and to

25 infiltrate optic nerve explants.

          Metalloproteases form an increasingly numerous
group, the members of which differ in their sensitivity to
various blockers. The most general blocker is 1,10-
phenanthroline which impaired C6 cell spreading on CNS

30 myelin up to 67%, whereas most inhibitors of the other
classes of proteases had no detectable effects. In the
early (90 minutes) but not the later (300 minutes) phases of
C6 cell spreading on myelin, an effect of trypsin-like
serine-protease inhibitors was also observed. The effect of

35 1,10-phenanthroline was dose-dependent, with an IC_{50} of 200
μM. This effect was specific for CNS myelin as a substrate,

since normal, rapid spreading of C6 cells was observed on
other substrates such as CNS grey matter, PNS myelin, glass
or PLYS in the presence of 1,10-phenanthroline. Other known
metalloprotease blockers like bestatine (inhibitor of

5 aminopeptidases; Umezawa, et al., 1976, J. Antibiot.
29:857-859), phosphoramidone (inhibitor of thermolysin-like
metalloproteases; Komiyama, et al., 1975, Biochem. Biophys.
Res. Commun. 65:352-357) and TIMP (inhibitor of ECM
degrading metalloproteases; Cawston, et al., 1981, 195:159-

10 165) did not lead to inhibition of C6 cell spreading on CNS
myelin. Since metalloproteases generally hydrolyze peptide
bonds followed by large aliphatic or neutral aromatic amino
acids, we tested the effect of dipeptide substrate analogues
containing such residues. Cbz-gly-phe-NH_2 (1 mM) or cbz-

15 tyr-tyr (0.3 mM) inhibited C6 cell spreading specifically on
CNS myelin. Cbz-gly-phe-NH_2 was found to inhibit other
1,10-phenanthroline sensitive enzyme activities with
relative high specificity (Almenoff and Orlowski, 1983,
Biochemistry 22:590-599; Baxter, et al., 1983, Proc. Natl.

20 Acad. Sci. U.S.A. 80:4174-4178; Couch and Strittmatter,
1983, Cell 32:257-265; Chen, J.M. and Chen, W.T., 1987, Cell
48:193-203; Lelkes and Pollard, 1987, J. Biol. Chem.
262:15496-14505).

Inactivity of C6-conditioned medium and cell

25 fractionation experiments demonstrated that the myelin-
directed proteolytic actiity is associated with C6 plasma
membranes. The isolation and characterization of a plasma
membrane-bound metalloprotease (endopeptidase 24.11,
enkephalinase), which is also blocked by 1,10-phenanthroline

30 but not by TIMP, was reported by Almenoff and Orlowski
(1983, supra). However, the metalloprotease described
herein is probably not an enkephalinase, since
carboxymethyl-phe-leu, a peptide with high affinity for
enkephalinase (Fournie-Zaluski, et al., 1983, J. Med. Chem.

35 26:60-65), did not affect C6 spreading on myelin. A
metalloprotease expressed by Rous sarcoma virus transformed

chick emb:yo fibroblasts and localized at adhesion sites and
on "invad:podia" was described by Chen, and Chen, 1987,
<u>supra</u>. This enzyme is also inhibited by 1,10-phenanthroline
and cbz-gly-phe-NH$_2$, but not by phosphoramidon, as is the
5 metalloprotease described here. However, unlike the enzyme
of Chen and Chen, we could not detect any fibronectin
degradative activity on C6 cells.

The highly metastatic B16 mouse melanoma cells
were tested in all the assays used with C6 cells. Interes-
10 tingly, B16 cells did not migrate into optic nerve explants,
but responded to the myelin-associated inhibitors in a way
very similar to 3T3 cells or neurons. In line with this <u>in</u>
<u>vitro</u> behavior, B16 cells, upon intraventricular injection,
form mainly meningiomas or intraventricular tumors without
15 significant infiltration of the brain parenchyma. Thus. the
mechanisms providing metastatic behavior to B16 cells in the
periphery are different from those conferring high mobility
to C6 cells in the CNS tissue.

Inhibition of C6-associated metalloprotease not
20 only inhibited C6 spreading on CNS myelin, but also
abolished C6 cell attachment, spreading, and migration on
CNS white matter, and the dipeptide, cbz-tyr-tyr strongly
impaired the migration of C6 cells into optic nerve
explants. This metalloprotease activity(ies) may,
25 therefore, be crucially involved in the infiltrative
behavior of C6 glioblastoma cells in CNS tissue, also <u>in</u>
<u>vivo</u>.

8. LONG DISTANCE TRACT REGENERATION IN THE
    LESIONED SPINAL CORD OF RATS BY A MONOCLONAL
30   ANTIBODY AGAINST MYELIN-ASSOCIATED NEURITE
    GROWTH INHIBITORS

The monoclonal antibody IN-1, which neutralizes
the inhibitory substrate effect of the 35 kD and 250 kD
myelin-associated proteins and of CNS tissue explants
35 (Caroni and Schwab, 1988, Neuron 1:85-96), was applied to
young rats intracerebrally by implanting antibody

producingtumors into the neocortex. Complete transections
of the cortico-spinal component of the pyramidal tract (CST)
at 2-4 weeks of age was followed by massive sprouting around
the lesion, and, in IN-1 treated rats, by elongation of fine
5   axons and fascicles up to 8-11 mm distal to the lesion
within 2 weeks. In control rats the maximal distance of
observed elongation rarely exceeded 1 mm. These results
demonstrate the induced regeneration capacity of a major
motor CNS tract within differentiated CNS tissue, and point
10   to the clinical importance of CNS neurite growth inhibitors
and their antagonists.

8.1.   MATERIALS AND METHODS

8.1.1.   PRE-OPERATIVE PREPARATION OF ANIMALS INCLUDING
15   IMPLANTATION OF HYBRIDOMA CELLS

Young Lewis rats (P2-11) were injected   ·
unilaterally under ether anesthesia into the dorsal frontal
cortex with 1 Mio. hybridoma cells in 1 or 2 μl. Control
rats were injected with the same number of cells of a
20   hybridoma line producing antibodies against horseradish
peroxidase (HRP). Non-injected controls were also used.
Hybridoma cells: IN-1 secreting cells were obtained by
fusion of P3U myeloma cells with spleen cells of a BALB/c
mouse immunized against the PAGE-purified 250 kD inhibitory
25   protein fraction from rat spinal cord myelin as described by
Caroni and Schwab (1988, Neuron 1:85-96); anti-HRP secreting
cells were obtained by Dr. P. Streit, Zurich, according to
the protocol of Semenenko et al. (1985 Histochem. 83:405-
408) using the same myeloma line (P3U) as for IN-1. In all·
30   hybridoma-injected rats, tumors formed within a few days as
solid, well delineated tumors often spanning the entire
thickness of the neocortex and contacting the lateral
ventricle (FIG. 16). Cyclosporin A injections (15 μg/g body
weight, 2 injections at 3 day intervals) helped to prevent
35   tumor resorption which otherwise occurred after 2-3 weeks.
Massive production of antibodies could be detected by

staining brain sections with anti-mouse Ig-FITC (FITC-
conjugated immunoglobulin) (FIG. 16b), and by the presence
of IN-1 antibodies in the serum (data not shown).

5   8.1.2.   PROCEDURE FOR PERFORMING SPINAL CORD LESION

Spinal cord lesions were placed at 2-4 weeks of
age (Table V, infra) at the thoracic level T_{5-7} by slightly
separating two vertebrae and transecting the dorsal two
thirds of the spinal cord with iridectomy scissors. The
10   lesion completely transsected the CSTs of both sides
including the lateral projections into the dorsal gray
matter, and also the central·canal. Ventral and lateral
white matter remained undisturbed, allowing the rats a
seemingly normal behavior. Lesions were done at 15-29 days
15   of age, i.e. 5-20 days after termination of axon growth in
the CST (Table V). A U-shaped stainless steel wire was then
implanted into the lesion site in order to assure complete
transection of both CSTs and to mark the lesion site. (The
wire was removed prior to embedding the fixed spinal cords
20· for sectioning).

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TABLE V

REGENERATION OF CORTICO-SPINAL TRACT AXONS AFTER MID-THORACIC LESIONS IN CONTROL AND ANTIBODY IN-1 TREATED RATS

Tumor-type	Day of lesion	Survival time	Max. distance of regenerated CST axons caudal to lesion
none	P 14	19 d.	0.1
			0.2
			0.2
			0.5
none	P 22	14 d.	0.4
			0.2
none	P 22	11 d.	0.7
			0.6
αHRP	P 15	14 d.	0.4
			1.0
			1.8
			2.6
αHRP	P 18	16 d.	0.1
			0.2
			0.2
			0.3
			0.4
			0.5
			0.8
IN-1	P 14	16 d.	2
			>8*
			11
IN-1	P 15	15 d.	4
			4.5
			>5*
			>5
			>5
IN-1	P 18	18 d.	2.5
			>3
IN-1	P 19	14 d.	7.7
			7.8
IN-1	P 28	14 d.	>4
			>4
IN-1	P 29	27 d.	>2.5

Methods as described in Fig. 17. Only rats with regenerative CST sprouts caudal to the lesion were included in this analysis. Distances of regenerating fibers are measured from the caudal edge of the lesion caverns. *Minimal distance as regenerating fibers reach the caudal end of the tissue block.

8.1.3.   POST1-LESION EVALUATION

After survival times of 14-28 days (Table V), the frontal and parietal cortex   contralateral to the tumor was injected with a 5% solution of WGA-HRP (1 μl). Twenty-four hours later, rats were perfused through the heart with 1.25% glutaraldehyde and 1% formaldehyde in 0.1 M phosphate buffer for 10 minutes. The dissected spinal cords (10-15 mm) were postfixed in the same fixative for 1 hour, extensively washed, and embeded for cryostat sectioning. Complete longitudinal section series were mounted on gelatin-coated slides, and reacted for HRP using TMB as a substrate (Mesulam, 1978, J. Histochem. & Cytochem. 26:106-117). Sections were viewed under dark-field illumination in polarized light. Only rats with complete bilateral CST lesions and with sprouts appearing on the caudal side of the lesion were evaluated.

8.2.   RESULTS: REGENERATION OF CORTICOSPINAL TRACT (CST) FIBERS OVER LONG DISTANCES IN RATS BEARING IN-1 SECRETING TUMORS

Two weeks after the lesions, at or beyond 1 month of age, the CST was labeled by anterograde transport of WGA-HRP from the frontal and parietal cortex. The histological examination of the lesion site in transverse and longitudinal sections showed a very similar picture in all animals: usually several small caverns were present and communicated with the central canal, a feature which probably greatly enhanced the local access and penetration of the antibodies carried down by the cerebrospinal fluid. The tissue was locally altered, but no dense glial scars were present. Labeled CST fibers approached the lesion as a dense and compact bundle from which massive sprouting occurred 0.5-1 mm proximal to the lesion. In most animals, controls or IN-1-injected, fiber plexus and bundles were

seen in and across the lesion area, most often circumventing the lesion caverns ventrally or laterally, but rarely also. growing through tissue bridges that had reformed in the wire tract. Fibers leaving the lesion site and travelling in a

5 caudal direction could frequently be observed. In animals without tumors and in rats with anti-HRP-producing tumors, the travelling distances measured on longitudinal sections from the distal edge of the lesion were in most instances below 1 mm (Table V, Figs. 17,18). Even relatively thick

10 fascicles seemed to end abruptly. Very much in contrast, animals bearing IN-1 secreting tumors consistently showed labelled fascicles and fibers at much longer distances caudal to the lesion (FIGS. 17,18). 2.5-5 mm were measured in most animals, 8 and 11 mm were seen in 2 rats (Table V).

15 Anatomically, these long distance regenerating CST fibers were most often found close to or in the original CST location, with some fibers also in the gray matter and a few fibers in more dorsal regions corresponding to the sensory tracts.

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8.3. DISCUSSION

In the rat, the CST is known to grow down the spinal cord during the first 10 postnatal days, the last axons being added at P9-P10 (Joosten et al., 1987, Dev.

25 Brain Res. 36:121-139; Schreyer and Jones, 1988 Dev. Brain Res. 38:103-119). Lesions of the tract up to P4-P5 lead to a circumvention of the lesion site and to long-distance, often ectopic growth of CST fibers (Schreyer and Jones, 1983, Neurosci. 9:31-40; Bernstein and Stelzner, 1983, J.

30 Comp. Neurol. 221:382-400). No regeneration in the CST has been seen after P6. A very similar lesion response has been observed in hamster and cat (Kalil and Reh, 1982, J. Comp. Neurol. 211:265-275; Tolbert and Der, 1987, J. Comp. Neurol. 260:299-311). For the cat it was demonstrated that these

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...bers are mostly late-arriving, newly-growing, rather than regenerating axons (Tolbert and Der, 1987, J. Comp. Neurol. <u>211</u>:265-275). The present results demonstrate that at least a small proportion of CST neurites at 2-3 weeks of age can

5 be induced to regenerate and elongate over long distances inside the spinal cord. The maximal speed of elongation is in the range of 0.5-1 mm/day.

Differentiated CNS tissue of mammals is a non-permissive substrate for neurite growth beyond a sprouting

10 distance of between 0.2-1 mm (Cajal, 1959, in "Degeneration and Regeneration of the Nervous System," ed. Hafner, New York, p. 1928; David, 1981, Science <u>214</u>:931-933; and Vidal-Sanz et al., 1987, J. Neurosci. <u>7</u>:2894-2909). This property is expressed (far more by CNS white matter than CNS gray

15 matter, as shown by culture experiments and by transplantation studies (Schwab and Thoenen, 1985, J. Neurosci. <u>5</u>:2415-2423; Carbonetto et al., 1987, J. Neurosci. <u>7</u>:610-620; Savio and Schwab, 1989, in press). Transplantations of fetal adrenergic or serotoninergic

20 neurons of defined fetal ages into adult spinal cords or hippocampus represent up to now the only other experiments where elongation of axons in adult CNS tissue was observed at an anatomical level (Nornes et al., 1983 Cell Tissues Res. 230:15-35; Foster et al., 1985 Exp. Brain Res. 60:427-

25 444 and Bjorklund et al., 1979 Brain Res. 170:409-426). These elongating axons were almost exclusively localized to gray matter areas.

Two oligodendrocyte- and myelin-associated membrane proteins, NI-35 (35 kD) and NI-250 (250 kD), with

30 potent inhibitory effects on neurite growth, were identified by <u>in</u> <u>vitro</u> and biochemical studies (Schwab and Caroni, 1988 J. Neurosci. <u>8</u>:2381-2393; Caroni and Schwab, 1988, J. Cell. Biol. <u>106</u>:1281-1288). Monoclonal antibody IN-1, which neutralizes the activity of these constituents in various <u>in</u>

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vitro systems including adult rat optic nerve explants
(Caroni and Schwab, 1988, Neuron 1:85-96), is shown here to
lead to true regeneration of cortico-spinal axons in young
rats over distances of up to 5-11 mm distal to a spinal cord
5 lesion within 2 weeks. The continuous supply of high levels
of antibodies via the cerebrospinal fluid by an antibody-
secreting tumor in the cortex, and the local conditions of
the lesion probably helped the penetration of the antibodies
into the tissue. The absence of axon elongation distal to
10 the lesion in spite of massive sprouting around the lesion
site in animals bearing control antibody tumors confirms the
specificity of the effect observed. These results clearly
demonstrate the ability of antibodies directed toward the
myelin-associated neurite growth inhibitor protein to induce
15 neuron fiber regeneration over long distances, as well as
the crucial role of the myelin-associated neurite growth
inhibitors for the absence of regeneration of lesioned CNS
fiber tracts observed under normal conditions.

20   9. DEPOSIT OF MICROORGANISMS
          The following hybridomas, producing the indicated
monoclonal antibodies, have been deposited with the European
Collection of Animal Cell Cultures (ECACC), PHLS Centre for
Applied Microbiology and Research, Porton Down, Salisbury,
25 Wiltshire, United Kingdom, and have been assigned the listed
accession numbers.

Hybridoma	Antibody	Accession Number
Cell line IN-1	IN-1	88102801
30 Cell line IN-2	IN-2	88102802

          The present invention is not be limited in scope
by the cell lines deposited or the embodiments disclosed in
the examples which are intended as illiustrations of a few
35

aspects of the invention and any embodiment which are functionally equivalent are within the scope of this invention. Indeed, various modifications of the invention in addition to those shown and described herein will become

5 apparent to those skilled in the art and are intended to fall within the scope of the appended claims.

Various references are cited herein, the disclosures of which are incorporated by reference herein in

10 their entireties.

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WHAT IS CLAIMED IS:

1. Monoclonal antibody IN-1, as produced by cell
line IN-1, as deposited with the ECACC and assigned
5 accession number 88102801.

2. Monoclonal antibody IN-2, as produced by cell
line IN-2, as deposited with the ECACC and assigned
accession number 88102802.
10

3. A neurite growth regulatory factor consisting
of a molecule, or derivative or fragment thereof,
characterized by the following properties:
    (a) metalloprotease activity;
15   (b) capable of being isolated from glioblastoma
        cells; and
    (c) capable of neutralizing the inhibitory
        substrate property of CNS myelin of a higher
        vertebrate, in which the neutralization is
20   detected by observing the ability of the CNS
        myelin in the presence of the factor to
        support neurite outgrowth or fibroblast
        spreading in vitro .

25   4. The factor of claim 3 in which the glioblastoma
cells are rat glioblastoma C6 cells.

5. A method for diagnosing a malignant tumor in a
patient comprising detecting the absence of a neurite growth
30 inhibitory factor in a sample containing central nervous
system myelin from the patient, in which the neurite growth
inhibitory factor comprises a protein, or derivative, or
fragment thereof, characterized by the following properties:

35

(a)   a nonpermissive substrate property as
      detected by the ability to inhibit neurite
      outgrowth or fibroblast spreading <u>in vitro</u>;
      and

5   (b)   capable of being isolated from central
      nervous system myelin of a higher vertebrate.

6.   The method according to claim 5 in which the
neurite growth inhibitory factor has an approximate
10 molecular weight of 35,000 daltons as determined by
polyacrylamide gel electrophoresis.

7.   The method according to claim 5 in which the
neruite growth inhibitory factor has an approximate
15 molecular weight of 250,000 daltons as determined by
polyacrylamide gel electrophoresis.

8.   A method for diagnosing a malignant tumor in a
patient comprising detecting the absence of a neurite growth
20 inhibitory factor in a sample containing central nervous
system myelin from the patient, in which the neurite growth
inhibitory factor comprises a protein, or derivative or
fragment thereof, characterized by the following properties:

(a)   a nonpermissive substrate property as
25   detected by the ability to inhibit neurite
      outgrowth or fibroblast spreading <u>in vitro</u>;
      and

(b)   the ability to be specifically bound by
      monoclonal antibody IN-2, as deposited with
30   the ECACC and assigned accession number
      88102802.

9.   The method according to claim 5 in which the
malignant tumor is a glioblastoma.

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10. The method according to claim 6 in which the malignant tumor is a glioblastoma.

11. The method according to claim 7 in which the
5   malignant tumor is a glioblastoma.

12. The method according to claim 8 in which the malignant tumor is a glioblastoma.

10   13. The method according to claim 5 in which the absence of the inhibitory factor is detected by observing the lack of binding of any component in the sample to an antibody or fragment thereof reactive with the inhibitory factor.
15

14. The method according to claim 8 in which the absence of the inhibitory factor is detected by observing the lack of binding of any component in the sample to an antibody or fragment thereof reactive with the inhibitory
20   factor.

15. The method according to claim 12 in which the antibody is selected from the group consisting of monoclonal antibody IN-1, as deposited with the ECACC and assigned
25   accession number 88102801, and monoclonal antibody IN-2, as deposited with the ECACC and assigned accession number 88102802.

16. A method for diagnosing a malignant tumor in a
30   patient comprising detecting the presence of the metalloprotease of claim 3 in a sample from the patient.

17. The method according to claim 15 in which the malignant tumor is a glioblastoma.
35

18. A pharmaceutical composition for treatment of a patient with a malignant tumor comprising an effective amount of a metalloprotease inhibitor in a suitable pharmacologic carrier.

5

19. The pharmaceutical composition of claim 18 in which the malignant tumor is a glioblastoma.

20. A pharmaceutical composition for treatment of 10 a patient with a malignant tumor comprising an effective amount of a compound which inhibits the metalloprotease activity of the factor of claim 3, in a suitable pharmacologic carrier.

15   21. The pharmaceutical composition of claim 20 in which the malignant tumor is a glioblastoma.

22. The pharmaceutical composition of claim 18 in which the metalloprotease inhibitor is selected from the 20 group consisting of 1,10 phenanthroline, ethylenediamine tetraacetate, ethyleneglycol-bis (β-aminoethyl ether) N, N, N'- N'-tetraacetate, carbobenzoxy-tyrosine-tyrosine, carbobenzoxy-glycine-phenylalanine-amide, carbobenzoxy-phenylalanine-tyrosine-amide, carbenzoxy-phenylalanine-25 phenylalanine-amide, and carbobenzoxy-glycine-phenylalanine-phenylalanine-amide.

23. The pharmaceutical composition of claim 20 in which the compound is selected from the group consisting of 30 1,10 phenanthroline, ethylenediamine tetraacetate, ethyleneglycol-bis (β-aminoethyl ether) N, N, N'- N'-tetraacetate, carbobenzoxy-tyrosine-tyrosine, carbobenzoxy-glycine-phenylalanine-amide, and carbobenzoxy-

35

phenylalanine-tyrosine-amide, carbobenzoxy-phenylalanine-phenylalanine-amide, and carbobenzoxy-glycine-phenylalanine-phenylalanine-amide.

5   24. A pharmaceutical composition for treatment of a patient with damage to the central nervous system comprising an effective amount of a substance which antagonizes the function of a neurite growth inhibitory factor, in a suitable pharmacologic carrier, in which the

10   neurite growth inhibitory factor comprises a protein, or derivative or fragment thereof, characterized by the following properties:

       (a)   a nonpermissive substrate property as detected by the ability to inhibit neurite

15   outgrowth or fibroblast spreading in vitro; and

       (b)   capable of being isolated from central nervous system myelin of a higher vertebrate.

20   25. The pharmaceutical composition of claim 24 in which the neurite growth inhibitory factor has an approximate molecular weight of 35,000 daltons as determined by polyacrylamide gel electrophoresis.

25   26. The pharmaceutical composition of claim 24 in which the neurite growth inhibitory factor has an approximate molecular weight of 250,000 daltons as determined by polyacrylamide gel electrophoresis.

30   27. The pharmaceutical composition of claim 24 in which the neurite growth inhibitory factor is specifically bound by monoclonal antibody IN-2, as deposited with the ECACC and assigned accession number 88102802.

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28. The pharmaceutical composition of claim 24 in which the antagonist substance is an antibody or binding region thereof.

5   29. The pharmaceutical composition of claim 25 in which the antagonist substance is an antibody or binding region thereof.

30. The pharmaceutical composition of claim 26 in which the antagonist substance is an antibody or binding region thereof.

31. The pharmaceutical composition of claim 27 in which the antagonist substance is an antibody or binding region thereof.

32. The pharmaceutical composition of claim 28 in which the antibody comprises monoclonal antibody IN-1, as produced by cell line IN-1, as deposited with the ECACC and assigned accession number 88102801.

33. The pharmaceutical composition of claim 28 in which the antibody comprises monoclonal antibody IN-2, as produced by cell line IN-2, as deposited with the ECACC and assigned accession number 88102802.

34. The pharmaceutical composition of claim 24 in which the damage is due to infarction, traumatic injury, surgical lesion or a degenerative disorder of the central nervous system.

35. The pharmaceutical composition of claim 24 in which the damage has occurred to the spinal cord.

36.   The pharmaceutical composition of claim 28,
29, 30 or 31 in which the antibody is administered by the
introduction into the patient of an antibody-secreting cell.

5   37.   A pharmaceutical composition for treatment of
a patient with a malignant tumor comprising an effective
amount of a neurite growth inhibitory factor in a suitable
pharmacologic carrier, in which the neruite growth
inhibitory factor comprises a protein, or derivative or
10 fragment thereof, characterized by the following properties:

      (a)   a nonpermissive substrate property as
            detected by the ability to inhibit neurite
            outgrowth or fibroblast spreading in vitro;
            and

15   (b)   capable of being isolated from central
            nervous system myelin of a higher vertebrate.

          38.   A pharmaceutical composition for treatment of
a patient with a malignant tumor comprising an effective
20 amount of a neurite growth inhibitory factor in a suitable
pharmacologic carrier, in which the neruite growth
inhibitory factor comprises:

      (a)   a nonpermissive substrate property as
            detected by the ability to inhibit neurite
25   outgrowth or fibroflast spreading in vitro;
            and

      (b)   the ability to be specifically bound by
            monoclonal antibody IN-2, as deposited with
            the ECACC and assigned accession number
30   88102802.

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39. The pharmaceutical composition of claim 37 in which the neurite growth inhibitory factor has an approximate molecular weight of 35,000 daltons as determined by polyacrylamide gel electrophoresis.

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40. The pharmaceutical composition of claim 37 in which the neurite growth inhibitory factor has an approximate molecular weight of 250,000 daltons as determined by polyacrylamide gel electrophoresis.

10

41. The pharmaceutical composition of claim 37, 38, 39 or 40 in which the malignant tumor is selected from the group consisting of a melanoma and a tumor of nerve tissue.

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42. A pharmaceutical composition for treatment of a patient with damage to the central nervous system comprising an effective amount of the factor of claim 3 in a suitable pharmacologic carrier.

20

43. A pharmaceutical composition for treatment of a patient with damage to the central nervous system comprising an effective amount of the factor of claim 4 in a suitable pharmacologic carrier.

25

44. The pharmaceutical composition according to claim 42 or 43 in which the damage is due to a stroke, traumatic injury, or a degenerative disorder of the central nervous system.

30

45. The pharmaceutical composition of claim 37 which further comprises a metalloprotease inhibitor.

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46. The pharmaceutical composition of claim 38 which further comprises a metalloprotease inhibitor.

47. The pharmaceutical composition of claim 39
5 which further comprises a metalloprotease inhibitor.

48. The pharmaceutical composition of claim 40 which further comprises a metalloprotease inhibitor.

10   49. The pharmaceutical composition of claim 45, 46, 47 or 48 in which the malignant tumor is selected from the group consisting of a melanoma and a tumor of nerve tissue.

15   50. The pharmaceutical composition of claim 45, 46, 47 or 48 in which the malignant tumor is a glioblastoma.

51. The pharmaceutical composition of claim 45, 46, 47 or 48 in which the metalloprotease inhibitor is
20 selected from the group consisting of 1,10 phenanthroline, ethylenediamine tetraacetate, ethyleneglycol-bis-(β-aminoethyl ether) N, N, N', N'-tetraacetate, carbobenzoxy-tyrosine-tyrosine, carbobenzoxy-glycine-phenylalanine-amide, carbobenzoxy-phenylalanine-tyrosine-amide, carbobenzoxy-
25 phenylalanine-phenylalanine-amide, and carbobenzoxy-glycine-phenylalanine-phenylalanine-amide.

52. A method for treating a patient with a malignant tumor comprising administering an effective amount
30 of a metalloprotease inhibitor to the patient.

53. The method according to claim 52 in which the malignant tumor is a glioblastoma.

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54.   A method for treating a patient with a
malignant tumor comprising administering an effective amount
to the patient of a compound which inhibits the
metalloprotease activity of the factor of claim 3.

5

55.   The method according to claim 54 in which the
malignant tumor is a glioblastoma.

56.   The method according to claim 52 in which the
10   metalloprotease inhibitor is selected from the group
consisting of 1,10 phenanthroline, ethylenediamine
tetraacetate, ethyleneglycol-bis (β-aminoethyl ether) N, N,
N'- N'-tetraacetate, carbobenzoxy-tyrosine-tyrosine,
carbobenzoxy-glycine-phenylalanine-amide, carbobenzoxy-
15   phenylalanine-tyrosine-amide, carbenzoxy-phenylalanine-
phenylalanine-amide, and carbobenzoxy-glycine-
phenylalanine-phenylalanine-amide.

57.   The method according to claim 54 in which the
20   compound is selected from the group consisting of 1,10
phenanthroline, ethylenediamine tetraacetate,
ethyleneglycol-bis (β-aminoethyl ether) N, N, N'- N'-
tetraacetate, carbobenzoxy-tyrosine-tyrosine, carbobenzoxy-
glycine-phenylalanine-amide, and carbobenzoxy-
25   phenylalanine-tyrosine-amide, carbobenzoxy-phenylalanine-
phenylalanine-amide, and carbobenzoxy-glycine-
phenylalanine-phenylalanine-amide.

58.   A method for treating a patient with damage to
30   the central nervous system comprising administering to the
patient an effective amount of a substance which antagonizes
the function of a neurite growth inhibitory factor, in which

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the neurite growth inhibitory factor comprises a protein, or derivative or fragment thereof, characterized by the following properties:

(a)   a nonpermissive substrate property as detected by the ability to inhibit neurite outgrowth or fibroblast spreading in vitro; and

(b)   capable of being isolated from central nervous system myelin of a higher vertebrate.

59.   The method according to claim 58 in which the neurite growth inhibitory factor has an approximate molecular weight of 35,000 daltons as determined by polyacrylamide gel electrophoresis.

60.   The method according to claim 58 in which the neurite growth inhibitory factor has an approximate molecular weight of 250,000 daltons as determined by polyacrylamide gel electrophoresis.

61.   The method according to claim 58 in which the antagonist substance is an antibody or a derivative or fragment thereof.

62.   The method according to claim 58 in which the damage is due to infarction, traumatic injury, surgical lesion or a degenerative disorder of the central nervous system.

63.   The method according to claim 62 in which the damage has occurred to the spinal cord.

64. The method according to claim 58, 59 or 60 in which the antagonist substance is an antibody, which antibody is administered by the introduction into the patient of an antibody-secreting cell.

5

65. The method according to claim 61, in which the antibody fragment or derivative is selected from the group consisting of the $F(ab')_2$, Fab', and Fab fragments.

10   66. A method for treating a patient with damage to the central nervous system comprising administering to the patient an effective amount of monoclonal antibody IN-1, or a fragment thereof containing the binding region, as produced by cell line IN-1, as deposited withthe ECACC and
15 assigned accession number 88102801.

67. The method according to claim 66 in which the antibody is administered by the introduction into the patient of an antibody-secreting cell.

20

68. A method for treating a patient with damage to the central nervous system comprising administering to the patient an effective amount of monoclonal antibody IN-2, or a fragment thereof containing the binding region, as
25 produced by cell line IN-2, as deposited with the ECACC and assigned accession number 88102802.

69. The method according to claim 68 in which the antibody is administered by the introduction into the
30 patient of an antibody-secreting cell.

70. A method for treating a patient with a malignant tumor comprising administering an effective amount of a neurite growth inhibitory factor to the patient, in

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which the neurite growth inhibitory factor comprises a protein, or derivative or fragment thereof, characterized by the following properties:

    (a)   a nonpermissive substrate property as detected by the ability to inhibit neurite outgrowth or fibroblast spreading in vitro; and

    (b)   capable of being isolated from central nervous system myelin of a higher vertebrate.

71. The method according to claim 70 in which the neurite growth inhibitory factor has an approximate molecular weight of 35,000 daltons as determined by polyacrylamide gel electrophoresis.

72. The method according to claim 70 in which the neurite growth inhibitory factor has an approximate molecular weight of 250,000 daltons as determined by polyacrylamide gel electrophoresis.

73. The method according to claim 70 in which the neurite growth inhibitory factor is specifically bound by monoclonal antibody IN-2, as deposited with the ECACC and assigned accession number 88102802.

74. A method for treating a patient with damage to the central nervous system comprising administering an effective amount of the factor of claim 3 to the patient.

75. The method according to claim 74 in which the damage is due to a stroke, traumatic injury, or a degenerative disorder of the central nervous system.

76. A method for treating a patient with damage to the central nervous system comprising administering an effective amount of the factor of claim 4 to the patient.

5   77. The method according to claim 76 in which the damage is due to a stroke, traumatic injury, or a degenerative disorder of the central nervous system.

78. A method for treating a patient with a
10 malignant tumor comprising administering to the patient an effective amount of a neurite growth inhibitory factor and an effective amount of a metalloprotease inhibitor, in which the neurite growth inhibitory factor comprises a protein, or derivative or fragment thereof, characterized by the
15 following properties:

     (a) a nonpermissive substrate property as
          detected by the ability to inhibit neurite
          outgrowth or fibroblast spreading in vitro;
          and
20   (b) capable of being isolated from central
          nervous system myelin of a higher vertebrate.

79. The method according to claim 78 in which the neurite growth inhibitory factor has an approximate
25 molecular weight of 35,000 daltons as determined by polyacrylamide gel electrophoresis.

80. The method according to claim 78 in which the neurite growth inhibitory factor has an approximate
30 molecular weight of 250,000 daltons as determined by polyacrylamide gel electrophoresis.

35

81. The method according to claim 78 in which the neurite growth inhibitory factor is specifically bound by monoclonal antibody IN-2, as deposited with the ECACC and assigned accession number 88102802.

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82. The method according to claim 78 in which the malignant tumor is a melanoma.

83. The method according to claim 78 in which the
10 malignant tumor is a tumor of nerve tissue.

84. The method according to claim 83 in which the tumor of nerve tissue is selected from the group consisting of a neuroblastoma and a glioblastoma.

15

85. The method according to claim 78 in which the metalloprotease inhibitor is selected from the group consisting of 1,10 phenanthroline, ethylenediamine tetraacetate, ethyleneglycol-bis-(β-aminoethyl ether) N, N,
20 N', N'-tetraacetate, carbobenzoxy-tyrosine-tyrosine, carbobenzoxy-glycine-phenylalanine-amide, carbobenzoxy-phenylalanine-tyrosine-amide, carbobenzoxy-phenylalanine-phenylalanine-amide, and carbobenzoxy-glycine-phenylalanine-phenylalanine-amide.

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FIG. 1A

FIG. 1B

FIG. 1C

FIG. 1D

FIG. 1F

FIG.1H

FIG. 1E

FIG. 1G

HIGHLY BRANCHED OLIGODENDROCYTES

FRACTION OF OLIGODENDROCYTES
SURFACE IN CONTACT WITH
SYMPATHETIC NEURONS OR
SCHWANN CELLS

FIG. 2A

HIGHLY BRANCHED OLIGODENDROCYTES

% OF OLIGODENDROCYTES
SURFACE IN CONTACT WITH
RETINA CELLS

FIG. 2C

IMMATURE OLIGODENDROCYTES

FRACTION OF OLIGODENDROCYTES
SURFACE IN CONTACT WITH
SYMPATHETIC NEURONS OR
SCHWANN CELLS

FIG. 2B

IMMATURE OLIGODENDROCYTES

% OF OLIGODENDROCYTES
SURFACE IN CONTACT WITH
RETINA CELLS

FIG. 2D

FIG. 3B

FIG. 3D

FIG. 3A

FIG. 3C

FIG. 4B

FIG. 4D

FIG. 4A

FIG. 4C

FIG. 4F

FIG. 4E

FIG. 5

HIGHLY BRANCHED
OLIGODENDROCYTES

FRACTION OF OLIGODENDROCYTE
SURFACE IN CONTACT WITH 3T3
CELLS

FIG. 6A

IMMATURE
OLIGODENDROCYTES

FRACTION OF OLIGODENDROCYTE
SURFACE IN CONTACT WITH 3T3
CELLS

FIG. 6B

FIG. 7B

FIG. 7D

FIG. 7A

FIG. 7C

NEUROBLASTOMA CELLS, 5HR

FIG. 8A

3T3 CELLS, 1HR
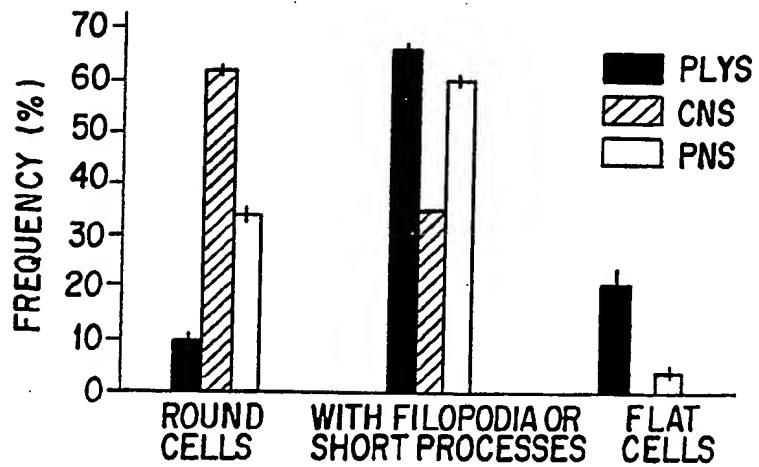
FIG. 8B
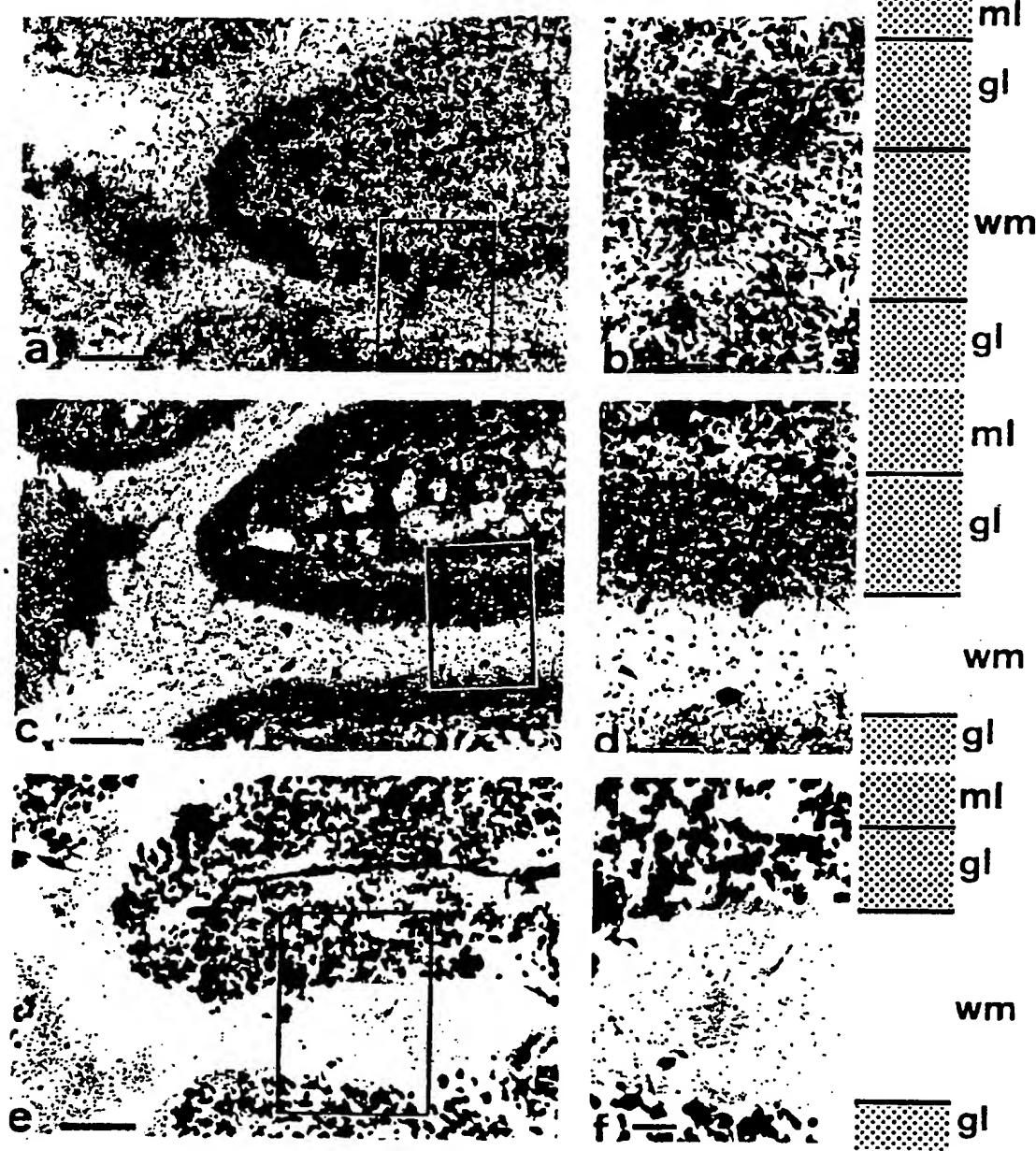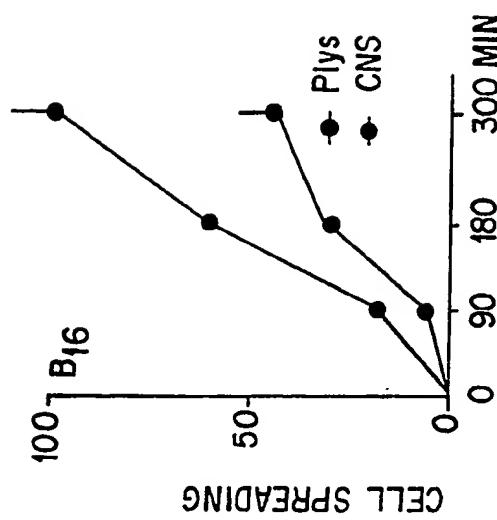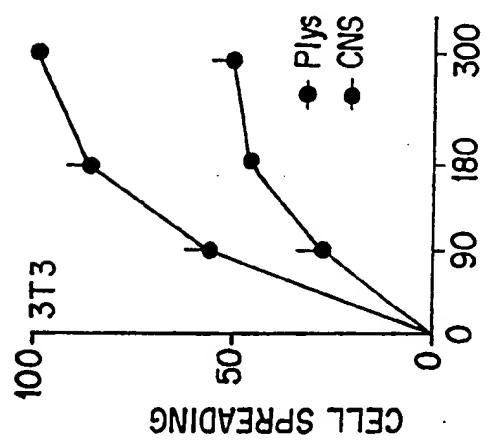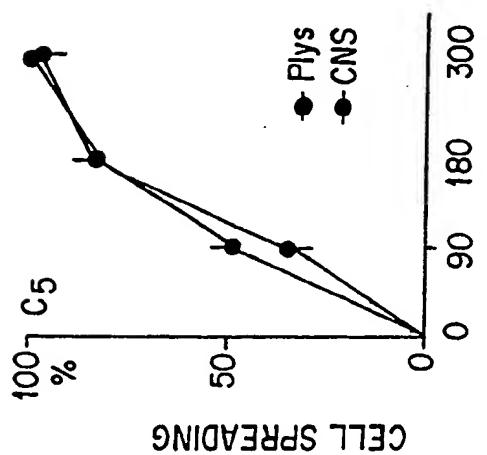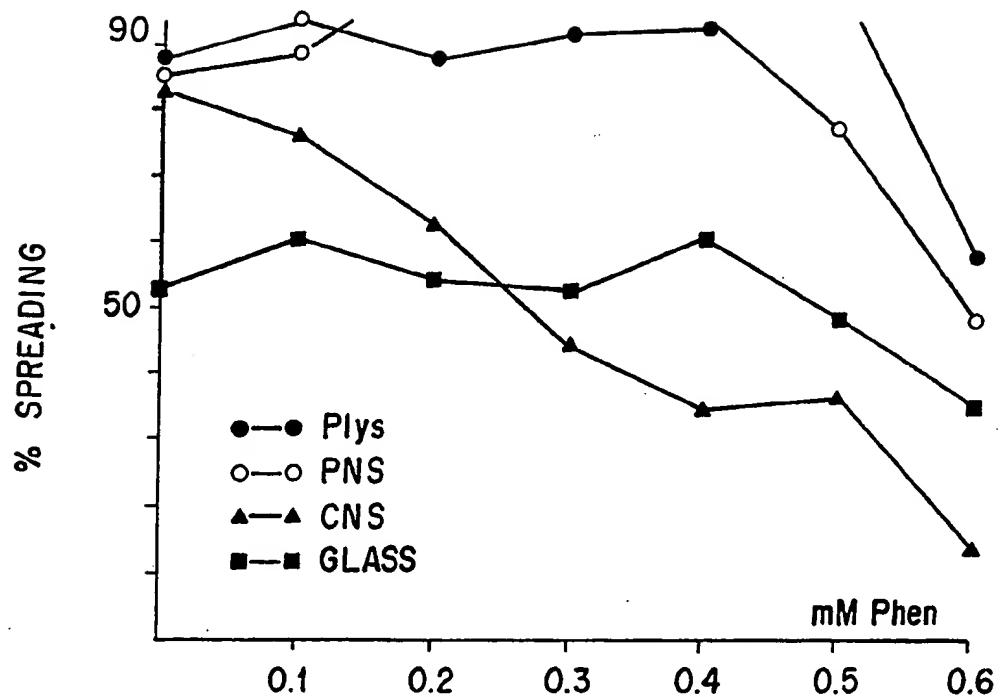
FIG. 9B

FIG. 9D

FIG. 9A

FIG. 9C

FIG. 10

CELL SPREADING

B16

100

50

0

0   90   180   300 MIN

● Plys
● CNS

FIG.11C

CELL SPREADING

3T3

100

50

0

0   90   180   300

● Plys
● CNS

FIG.11B

CELL SPREADING

C5

100 %

50

0

0   90   180   300

● Plys
● CNS

FIG.11A

FIG. 12

FIG. 13B

FIG. 13A

FIG. 13D

FIG. 13C

FIG. 14A

FIG. 14B

FIG. 15

FIG. 16A   FIG. 16B

IN-1
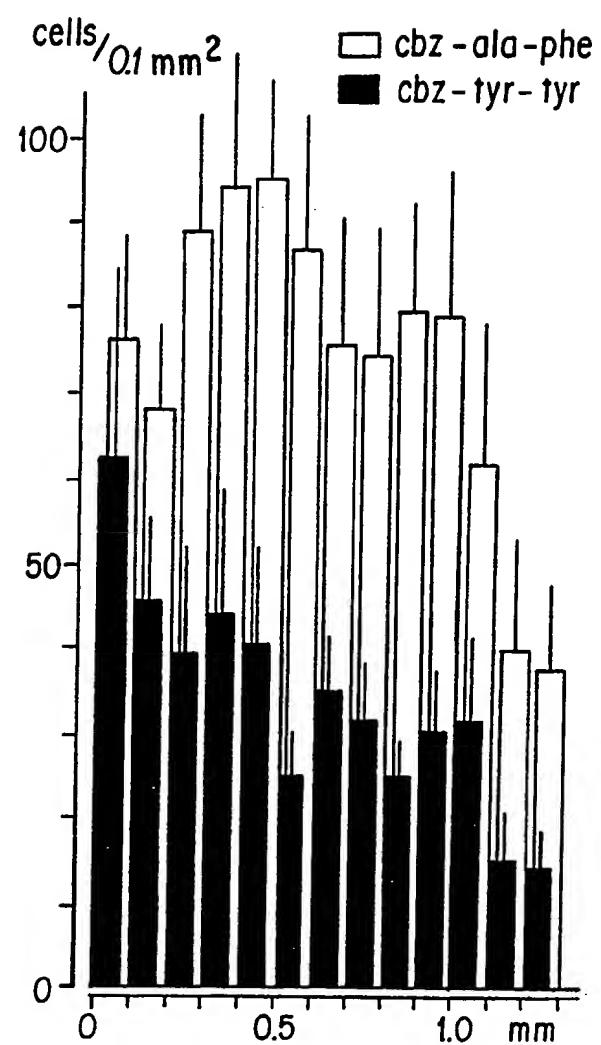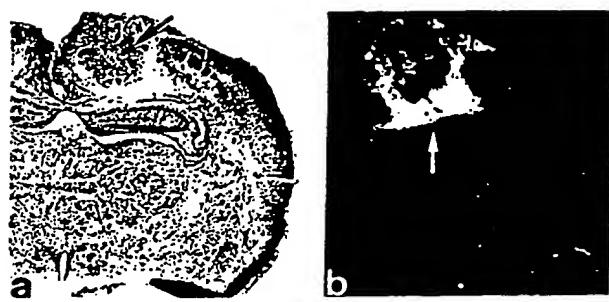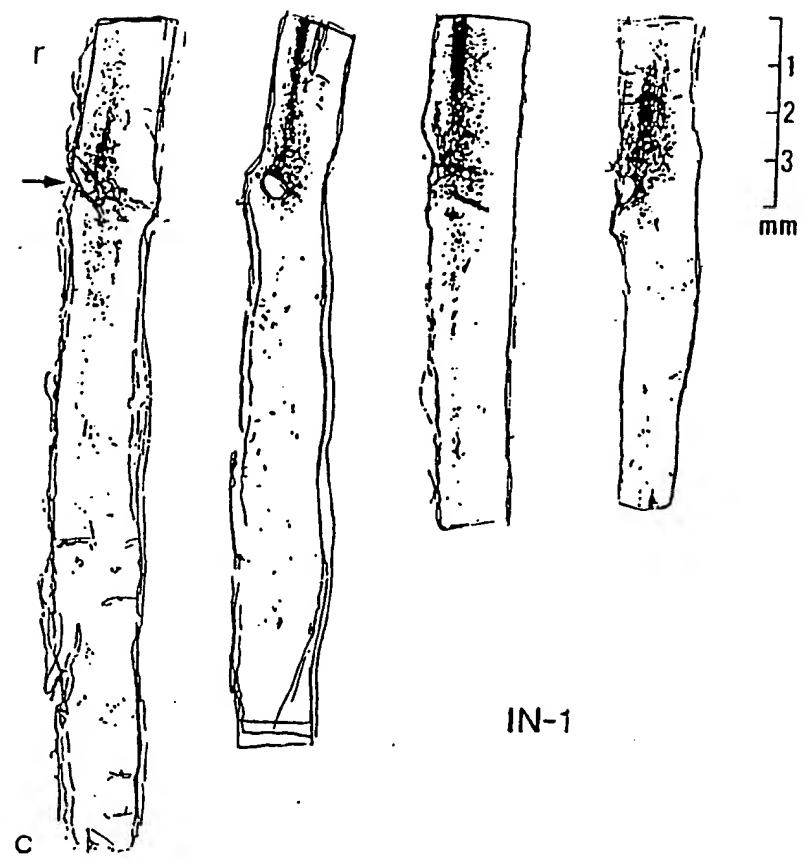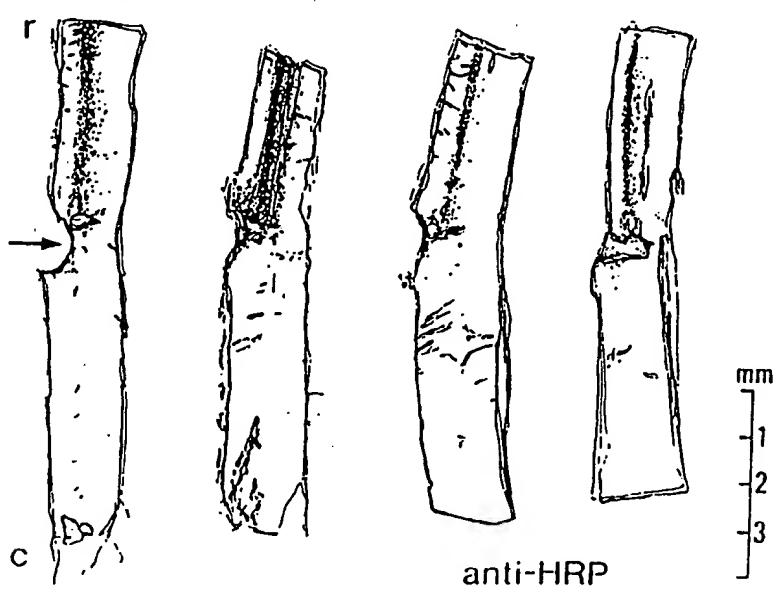
anti-HRP

FIG. 17

FIG. 18
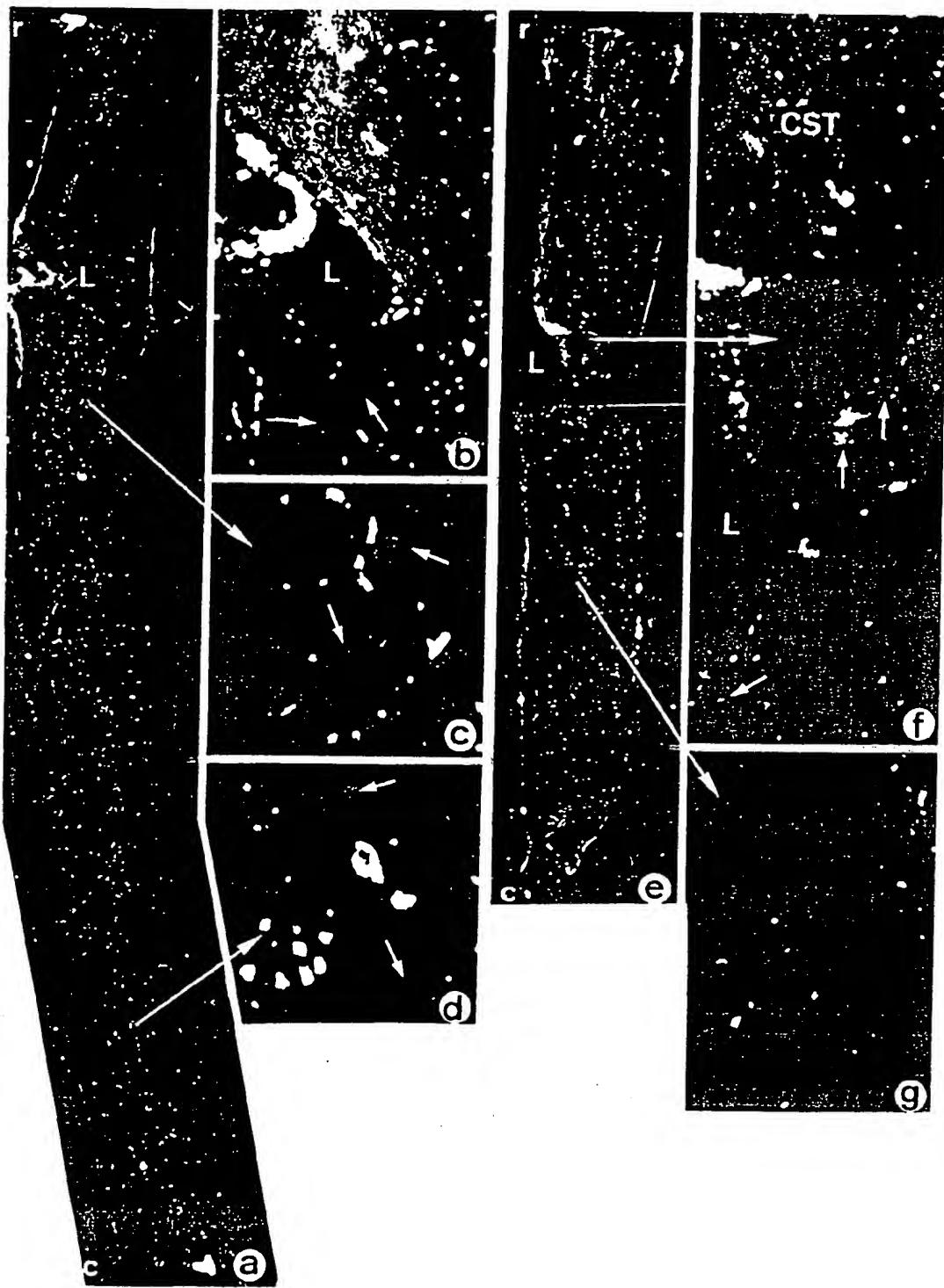
INTERNATIONAL SEARCH REPORT

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) *

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: C 12 P 21/08, G 01 N 33/53, C 07 K 15/28, 15/06
A 61 K 37/64, 37/54

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC5	C 07 K; A 61 K

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched 8

III. DOCUMENTS CONSIDERED TO BE RELEVANT *

Category *	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No. 13
P,X	The Journal of Cell Biology, Vol. 107, No. 6, December 1988, P.A. Paganetti et al: "Glioblastoma Infiltration into Central Nervous System Tissue in Vitro: Involvement of a Metalloprotease ", see page 2281 - page 2291	18-23
X	Neuron., Vol. 1, March 1988, P. Caroni et al: "Antibody against myelin-associated inhibitor of neurite growth neutalizes nonpermissive substrate properties of CNS white matter. ", see page 85 - page 96	1-4
Y		5-17,24-35,42-44

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
20th February 1990	- 7. 03. 09

International Searching Authority	Signature of Authorised Officer
EUROPEAN PATENT OFFICE	T.K. WILLIS

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Categ.	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X	The Journal of Cell Biology, Vol. 106, April 1988, P. Caroni et al: "Two membrane protein fractions from rat central myelin with inhibitory properties for neurite growth and fibroblast spreading. ", see page 1281 - page 1288	1-4
Y		5-17,24-35,42-44
A	Brain Research, Vol. 262, 1983, Y. Sakazaki et al: "Characterization and partial purification of neuroblastoma growth inhibitory factor from the culture medium of glioblasts. ", see page 125 - page 135	3,4,18-44
A	Chemical Abstracts, volume 103, no., 23 December 1985, (Columbus, Ohio, US), Guenther Joachim et al : "A glia-derived neurite-promoting factor with protease inhibitory activity. ", see page 231, abstract 207640z, & EMBO J. 1985, 4(8), 1963- 6L	3,4
A	EP, A1, 0155433 (FONTANA ADRIANO, SECTION OF CLINICAL IMMUNOLOGY DEPT. OF INTERNAL MEDICINE UNIVERSITY HOSPITAL) 25 September 1985, see page 4, lines 16-25, pages 17-20 and claim 4	3,4
A	EP, A1, 0159289 (SANDOZ AG) 23 October 1985, see page 1 lines 27-30, page 4, line 26 - page 5 and claims 1-5	3,4
Y	EP, A2, 0233838 (CIBA-GEIGY AG) 26 August 1987, see page 2 and page 14, lines 35-59	24-35, 42-44

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category*	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X	Chemical Abstracts, volume 90, no. 9, 26 February 1979, (Columbus, Ohio, US), W.A. Boggust et al: "Inhibition of collagen peptidase in HeLa cells and human tumors by compounds including drugs used in cancer therapy.", see page 19, abstract 66525q, & Br. J. Cancer 1978, 38(2), 329-34	18,20, 22,23.
	--	
T	Journal of Neurochemistry, Vol., 1989, (New York) R. Hammerschlag et al: "Metalloendoprotease inhibitors block fast axonal transport", see page 268-73	18-23, 45-51
	--	
A	Biochemical Pharmacology, Vol. 36, No. 7, 1987, C.B. Caputo et al: "Proteoglycan degradation by a chondrocyte metalloprotease.", see page 995 - page 1002 and page 995 and table 1	18-23 45-51
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FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. [X] OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. [X] Claim numbers 52-88 because they relate to subject matter not required to be searched by this Authority, namely:

See PCT Rule 39.1(iv)

Method for treatment of the human or animal body by means of surgery or therapy, as well as diagnostic methods.

2. [ ] Claim numbers........... because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claim numbers........... because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. [ ] OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this International search report covers all searchable claims of the international application.

2. [ ] As only some of the required additional search fees were timely paid by the applicant, this International search report covers only those claims of the international application for which fees were paid, specifically claims:

3. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. [ ] As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

[ ] The additional search fees were accompanied by applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (supplemental sheet (2)) (January 1985)

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on   08/11/89
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A1- 0155433	25/09/85	WO-A-	85/04421	10/10/85
		AU-D-	41576/85	01/11/85
		JP-T-	61501514	24/07/86
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